AGRICULTURAL AND ECONOMIC IMPACT OF TRUE POTATO SEED TECHNOLOGY ON THE EU POTATO INDUSTRY; AN EX-ANTE ASSESSMENT

By

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ABSTRACT

Adequate supply of healthy planting material, at reasonable prices, is of critical importance to the functioning of the potato industry. True Potato Seed (TPS) technology offers an alternative way to produce potato planting material, based on the use of botanical potato seeds.

This study investigates the hypothesis that the use of TPS technology, in a similar way as practised in the USA, will be beneficial to the European Union. It is assumed that the TPS varieties that have been bred in the USA are also capable of meeting the demands of the EU markets

The current status of the EU potato industry and the working of TPS technology are reviewed. As part of this study botanical potato seeds from nine TPS varieties that are commercially available in the USA, have been imported into and used to initiate the first ever field trials within the European Union.

A large mathematical model has been purposely build to simulate the uptake of TPS technology by the EU potato industry, and to assess the agronomic and economic effects. The modelling results, of various scenario's all indicate that the use of TPS technology would bring economic and agricultural benefits to the EU. The annual savings could be as high as 130 million ECU per year, whilst reducing the potato growing area with up to 72,000 ha

Implications of these finding, and current limitations to the uptake of TPS technology inside the EU are discussed.

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I also want to thank Genessee Investments for supplying my University fees for the third year, and allowing me to undertake TPS-fact finding studies to Latin America and South Africa. Last but certainly not least I would like to thank all the taxpaying citizens of the European Union, who enabled me to undertake this study through a two-year grant under the Human Capital and Mobility scheme. May there soon come a day that you can all enjoy the additional option of eating potatoes that are grown with TPS technology.

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LIST OF ABBREVIATIONS

cv	cultivar
CIP	International Potato Centre
EAPR	European Association for Potato Research
ECU	European Currancy Unit
EU-15	European Union: Austria, Belgium, Denmark, Finland,France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, UK,
EU-12	European Union before January 1995, i.e.without Austria, Finland and Sweden.
EU-4	Spain, Portugal, Italy and Greece
IERM	Institute of Ecology and Resource Management
IGM	Improved Gross Margin
FAO	Food and Agricultural Organisation
FDR	First Division Restitution
FGP	Final Germination Percentage
ga	gilliberic acid
GCA	General Combining Ability
H	hybrid seed
ISAR	
LP	Linear Programming
NIVAA	Netherlands Potato Consultative Organisation
NPC	National Potato Council (USA)
NUTS	Nomenclature des Unites Territoriales Statistiques
PAA	Potato Association of America
PMB	Potato Marketing Board (UK)
op	open pollinated (seed)
SAC	Scottish Agricultural College
SASA	Scottish Agricultural Science Agency
SCRI	Scottish Crop Research Institute
STOPA	Foundation regulating the export prices of Dutch seed potatoes
TPS	True Potato Seed
WAU	Wageningen Agricultural University
ZMP	Zentralle Markt- und Preisberichtstelle

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1.1 T

The valu ... otato industry. ... nced that the t ... d in reality, ar ... are equally knowledgeable scientists and professionals who see it as a solution to some of the most important problems of the industry (Upadhya, 1996). Despite several decades of research and discussion, this technology has not been subjected to much economic analysis.

Discussion about the value of TPS technology is not only of academic interest. At stake is the way in which the world's fourth most important food crop is being propagated. To a country like the Netherlands the consequences could be enormous, for its annual export of seed potatoes measures several hundred millions ECU's. According to some, this entire trade could collapse if TPS technology becomes successful. Thus it is no surprise that these exporters can generate a multitude of arguments as to why TPS technology can never (be allowed to) become successful.

Different arguments can be heard from prestigious institutes such as the International Potato Center, which have spent a considerable amount of their budget on the development of TPS technology, over a long period of time. If the technology becomes successful, it will be hailed as "another green revolution" (Sawyer, 1979). But if a breakthrough proves unattainable, international donors will question the wisdom of the entire R&D program. The argument that more funding would have led to more results,

[1] This chapter includes material that has previously been presented in the paper " Modeling the Economic and Agricultural Impact of TPS-Utilization in Countries of the European Union" by Renia,H.,Anderson,J.L.,Dent,J.B.,Lilwall,N.B. as presented at the 13th Triennial Conference of the European Association for Potato Research in Veldhoven, The Netherlands, 14-19 July 1996.

may not be convincing to all.

Furthermore one can find private companies in the USA and other countries that have already invested tens of millions of dollars in an attempt to make TPS technology a commercial success. They are balancing the individual expenses against the (expected) individual returns. Scientific progress is only interesting insofar as it improves the expected profits.

The discussion about the role and value of TPS technology can easily become blurred by vested interests, by a lack of understanding about the technology itself and by a lack of knowledge about the latest scientific developments. At present the technology is not (yet) widely accepted as a serious alternative to the more traditional method of potato multiplication.

At the same time some significant changes are taking place that support the position of TPS technology; The United States Department of Agriculture has changed the legislation in order to allow the import of TPS from Chile (USDA, 1995). In India the annual production of TPS has increased to more than 500 kg in 1996 (Upadhya, 1996). Furthermore countries like South Africa, and Peru are changing the legislation seed potato certification in favor of TPS.

A surprising side of the discussion about TPS technology is the apparent lack of economic analysis, despite the fact that the technology promises several economic advantages; eg the cost of potato planting material may be expected to be greatly reduced. The cost associated with the handling, storage and transport of the TPS is just a fraction of those associated with the handling, storage and transport of seed potato tubers. Furthermore the increased use of healthier planting material would greatly reduce the need for chemicals during the growing season.

One would expect that the proponents of this technology would be the first to demonstrate the high value of this "miracle technology", and thus secure the funding to develop it. Equally it would be expected that the antagonists of the technology would demonstrate the utter uselessness of the technology, and thus prevent the wastage of more scarce resources. As far as the author could ascertain, there have been only a handful of economic assessments of TPS technology, most of them dealing with the partial assessment of isolated cases. The first comprehensive ex-ante assessment of TPS technology was published as late as 1996, by Khatana et al. al., and was restricted to the eastern and northeastern part of India.

The basic aim of this study is to shed more light on the economic value and impact of TPS technology. An ex-ante assessment has been made for the Potato Industry of the European Union. It is thought the results from this assessment will prove to be useful to policy makers who decide about the allocation of research funding, as well as legislation.

This introductionary chapter consists of five sections. Section 1.2 briefly reviews the role of the potato in the world, and the problems of its propagation. In section 1.3 the academic side of the problem is defined in more detail, as well as the aim of the study and the hypothesis that will be tested. Section 1.4 presents the scientific framework in which this study has been carried out. The last section (1.5) outlines the structure of the thesis as a whole and the individual chapters.

1.2 The potato and its propagation

The potato (*Solanum tuberosum*) is a major source of food worldwide. In terms of production, the crop ranks fourth, directly after wheat, rice and maize (Horton, 1987; FAO 1993). The potato produces more edible energy and protein per hectare than most food crops, and it also has a high level for the daily production of energy and protein (Zaag et al, 1983, Woolfe, 1987). Potatoes are grown in more than 125 countries (Horton, 1987). Since World War II the potato production area has decreased in Europe, but increased significantly in the developing world (FAO, 1991). However as much as

40 % of the global potato production takes place in Europe and North America (see Table 1.1.)

Table 1.1 Overview of the world potato production 1993.

Region	Area (1000 ha.)	Production (1000 t)	Yield (t/ha)
Europe	4,088	95,703	23.4
EU-12	1,381	45,241	32.8
EU-15	1,489	47,883	32.2
CIS*	6,313	77,914	12.3
Asia	5,213	70,451	13.5
N&C America	767	24,008	31.3
S-America	927	11,219	12.1
Africa	780	7,496	9.6
Oceania	45	1,392	28.1
World	18,133	288,183	15.9

*estimate

Source: FAO 1994.

The accepted method of potato propagation is by means of vegetative multiplication. Tubers from the previous harvest are used as planting material for the next season. Such tubers are widely known as seed potatoes. Factually this is not correct since seeds are the result of a sexual reproduction process that involves flowering, pollination and eventually seed production.

The vegetative multiplication system is considered to be troublesome and expensive. The planting material is bulky, perishable and capable of transmitting a large number of diseases. Furthermore the multiplication rates are very low. Compared to the other important food crops, the potato clearly lags behind in its multiplication performance (see table 1.2).

Table 1.2 Multiplication rate and seed rate per ha for various crops.

	Seed Rate (Kg)	Yield (Kg)	Mutiplication rate	Acreage ratio of seed crop to commercial crop
Maize	25-40	6,000	240-150	1:100
Barley	80-120	5,000	60-40	1: 40
Wheat	129-160	5,000	40-30	1: 30
Potato	1500-2500	30,000	20-12	1: 10

Source: Beukema et al, 1990

The low multiplication rate of potatoes, requires specialized schemes for the production of virus free seed potatoes, which have a time lag of at least 8 years before the production of ware potatoes can take place (Allan et al., 1992). During the many years of seed multiplication, the seed potatoes can easily become infected by various diseases. Without exception these diseases will be transmitted to the following generations. The large volume and weight (2 - 3 t/ha) of seed potatoes that is needed to plant one hectare, leads to high transport and storage costs. Many potato producing countries lack either the physical or socio-economical conditions to establish and maintain a functional seed potato multiplication system. Thus they become dependent on either imported seed potatoes or on seed potatoes of sub-standard quality (Wiersema, 1984).

The community of potato researchers is well aware of these problems and has identified four different types of technology that may help solve some of the current problems. These technologies involve; (1) the use of in-vitro tissue-cultures for the production of mini-tubers (Lommen, 1995); (2) micro-tubers (Haverkort et al. 1991); (3) the production of aerial tubers above the ground level (Percival, 1996) and (4) the production of botanical potato seed (TPS), which is based on the sexual propagation of the potato crop (Almekinders, 1995).

Research on all these technologies is on going throughout the world, albeit with different budgets. The economic success of any new method of potato multiplication will depend on factors such as technical performance, price and the present situation of seed supply of the country in which it will be used (Zaag, 1992).

1.3 Problem, Objectives and Hypothesis of this Study

A new technology for the propagation of potatoes will attract substantial costs in the various stages of its generation, development, introduction and dissemination. This would not be a problem, as long as the sum of revenues outweighs the sum of the expenses. The real problem lies in the correct assessment of both the future benefits, as well as the costs for research and development. Since the resources for agricultural research are limited, it is highly desirable for policy-makers to assess the likely impact of research projects so as to make the best decision regarding the continuation of a certain research project (Alston et al., 1995).

The problem for the potato industry is the apparent lack of methodological tools to assess the economic value of new technologies for potato propagation, as well as many other aspects of potato production. Thus it is possible that scarce resources will be sacrificed to study and develop alternative technologies that can never hope to become viable in the daily practice of potato production. This problem is not unique to either the potato industry or the EU.

The objective of this study is to assess the likely impact of USA-style TPS technology on the potato industry of the European Union. The assessment will be conducted by means of a mathematical simulation model. Since the underlying principles of the methodology are identical for other geographic regions and other technologies of potato propagation, this specific methodology may be adapted for utilization elsewhere and for other technologies. The choice to focus the methodological development on the European Union and TPS technology was made because the EU represents a significant portion (16 %) of the world potato production, and is relatively well documented.

Furthermore it is generally accepted that multinational seed companies, initially have to recoup their investments in new technologies from the industrialized regions of Europe, North America and Japan. (Gaasbeek et al, 1994). For the potato crop it makes sense to study the impact of a new technology on the EU, since its potato industry is larger than that of North America and Japan combined. If it works for the EU, it will most likely work elsewhere as well.

The value of the EU potato industry (at producer level) measured 5.1 billion ECU in 1991. (European Commission, 1996). Therefore a modest saving of just 1 % in the cost of potato production, represents a value of some 50 million ECU per year. This is several times the total annual budget of potato research establishments like the SCRI or CIP.

The decision to assess the impact of TPS technology, to the exclusion of other new technologies, was inspired by the tremendous hopes and fears surrounding TPS in the community of potato professionals. Although TPS technology does not promise an increase in yields above that of clonally multiplied potato varieties, it does promise substantial savings in the cost of planting material and the need for chemicals to maintain health. TPS technology may perhaps be compared to "the holy grail" in the world of potato production. Supposing that it can be found, what would be a rational price to pay for it ? Furthermore the import and sale of TPS is (currently) legally prohibited in Europe, in contrast to the situation in the USA. What is the size of the opportunity costs of prohibiting the use imported TPS to the EU-potato Industry ? The use of TPS technology in the EU is expected to generate substantial savings in terms of lower potato production costs, as well as a decreased usage of chemicals to compensate for the usage of low quality uncertified seed.

This study sets out to test the specific hypotheses that:

H_0 The utilization of (USA style) TPS technology will be economically beneficial to the EU potato industry.

against the alternative hypothesis that:

H_1 The utilization of (USA style) TPS technology will not be economically beneficial to the EU potato industry.

Hereby USA-style TPS technology is defined as the use of botanical potato seed, of potato hybrids that have been bred in the USA, for the production of high quality and seed potato tubers. It also implies the direct seeding of the botanical seed is into the open field, and the expectation of commercial yields from the seedling tubers that are equal to those of commercially available clonal potato varieties, as well as tuber characteristics that are capable to meet the quality standards of industrialized countries.

Rejection of the Ho hypothesis will support the policy decisions not to lift the ban on the import of TPS and not to invest more in the R&D of this technology. In the case that the Ho can not be rejected, the conclusion must follow that there are sound reasons to lift the import ban, and allocate more resources towards the development of TPS technology for the EU situation.

1.4 Scientific framework

The scientific ideal in assessing the value of a new technology is to measure its performance in a number of representative locations throughout the EU, over a representative number of production cycles. For TPS technology, six to twelve field trials per EU country, located on "typical" soil types and "normal" production units, for two or three growing seasons would be required. From these types of measurements one could than extrapolate the impact of the technology on the whole of the EU.

This avenue was not available for this Ph.D.-project, even if sufficient funding had been available to carry out such a great number of field trials. The EU import restrictions on TPS make it virtually impossible to conduct field trials with TPS varieties that are commercially available in the USA. It even proved that carrying out a basic economic study of TPS varieties from the USA, requires an official permit from the plant health authorities in the UK (see Appendix 1). During the course of this project it has been possible to import a small quantity of TPS of USA-varieties, which has germinated in quarantine, and from which the tubers will be used for two field trials in the UK in 1997 and 1998. The amount of data that is expected from these trials will be insufficient to serve as a basis for an EU -wide assessment of TPS technology.

In the absence of a measurable reality, the only route open has been to simulate both the EU potato industry and the impact of USA-style TPS technology. USA-style TPS technology The simulation was done by means of a large LP-matrix, whereby the EU potato industry was given the choice to produce potatoes by either using the conventional propagation method, TPS technology, or a combination of both. The modeling results will then be used to test the hypothesis that was formulated in section 1.3.

1.5 Thesis outline

The thesis consists of nine chapters, of which the first provides the general introduction to the study. The chapters 2 and 3 provide a background of the two main study objects namely the EU potato industry and the TPS technology. These are followed by chapter 4 in which the first ever trials with commercial TPS in the European Union, which have been initiated as part of this research project, are described.

In chapter 5 the theoretical options in assessing a new technology are explored, and the need to use a purpose build mathematical model is identified. Chapter 6 describes the developmental process of a mathematical simulation model for the EU potato industry. This model is then validated and analyzed on its sensitivity in chapter 7. Chapter 8 discusses the modeling results for a number of different uptake scenarios for TPS technology in the EU.

The thesis is concluded by chapter 9, in which the usefulness of the simulation model and the future role of TPS technology in the EU are discussed. The thesis does not pretend to provide the conclusive argument in the controversy surrounding the TPS discussion, but it is hoped that it will make a positive contribution to an improved understanding of the potential of this technology.

2. OVERVIEW OF THE EU POTATO INDUSTRY [1]

2.1 Introduction

The potato came to Europe during the last quarter of the 16 century, but only became a staple food after a slow and troublesome start.(Hawkes, 1992). The annual area that is currently being used for potato production in the EU measures 1.5 million ha. and involves more than one million professional growers (Eurostat, 1996). The EU potato industry also plays an important role both within the context of European agriculture and food supply as well as the rest of the world (FAO, 1995).

In terms of global potato production the EU ranks second after Russia, and in terms of planted area is ranks fifth after Russia, China, Poland and the Ukraine (ZMP, 1995). Because of the high average yields of around 29.5 t/ha (ZMP, 1995) the EU uses only a modest 8 to 9 % of the world potato growing area to generate 16 % of the global potato production (based on 1994 figures). In 1995 the potato production of the EU-15 measured 44.6 million t. The 1991 farm gate value of the EU potato crop lay at more than 5.1 billion ECU (European Commission, 1995).

For most of the 371 million inhabitants of the EU the potato and its derived products are a staple food. The average consumption of potatoes in the EU lies just above 80 kg. per head (ZMP, 1992). The potato is currently one of the few agricultural products in the Union that has not yet been subjected to a Common Agricultural Policy Regime. Within EU agriculture, the potato crop accounts for just over 1 % of the arable area.

Two factors make it difficult to obtain a clear and reliable overview of the EU potato industry. Firstly because the industry itself is a very large, complex and dynamic entity. Secondly because the quality and quantity of information about the industry varies

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[1] This chapter includes material of the paper " The EU-15 Potato Industry " by Renia, Anderson, Dent and Lilwall. Earlier presented at the 80th Annual Conference of the Potato Association of America Idaho Falls, USA 11-15 August 1996.

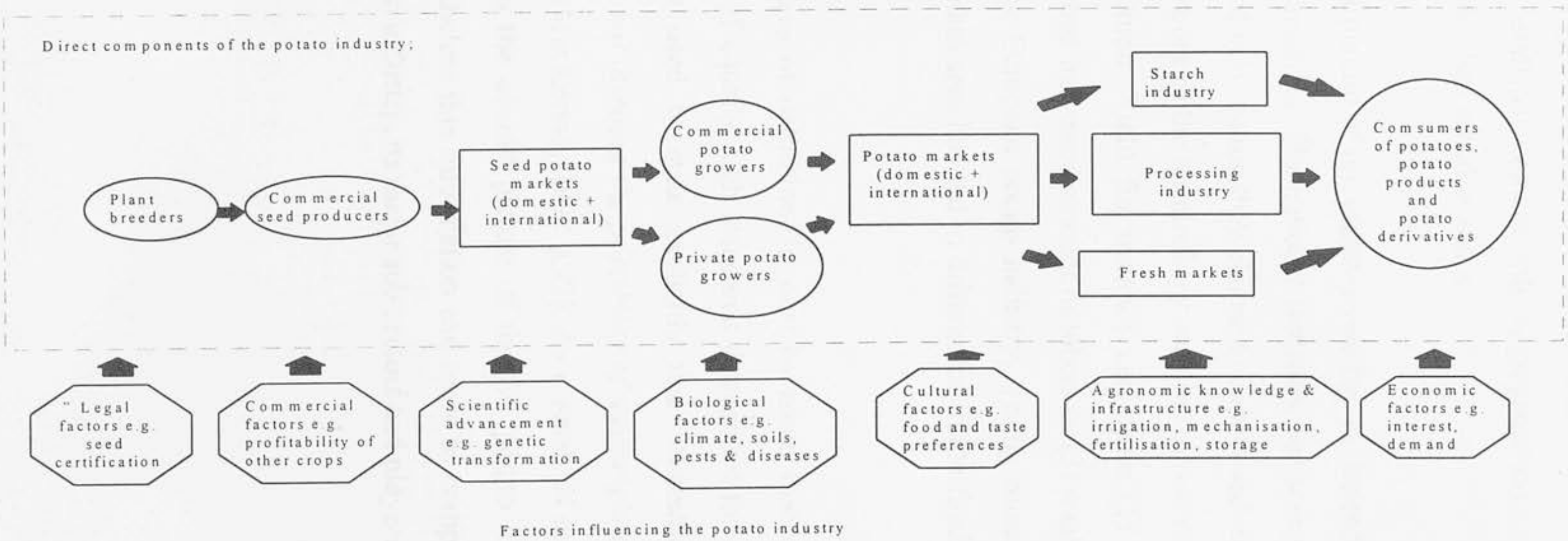
greatly between the EU member states. This chapter aims to present an overview of the current state of the EU potato industry and its most important sub-sectors.

The potato industry is complex because it consists of numerous sub-sectors that are co-dependent in many different ways. (See Fig. 2.1) The industry can be divided into core sectors such as plant breeding, seed production, potato production, potato trade and consumption. In real life the separation between the above sectors is blurred since many of the players in one particular sub-sector are also involved with other sectors of either the potato industry or indeed with other industries.

The individual potato consumer for instance is free to buy frozen French fries from a retail outlet, or to grow potatoes as a hobby and subsequently produce his own fries. Equally the multinational processing company can chose to either buy "what the market offers" or to become vertically integrated and also become involved in plant breeding, seed production and trade. In most situations the final result is such that actors in the industry are involved in more than one sub-sector, with the option to increase or decrease their involvement at relatively short notice.

At the periphery of the potato industry lie a number of factors that influence the functioning of the potato industry, but that can also become influenced by the potato industry. The history of McDonalds is a good example how at first the catering industry influenced the processing and culture of one country, which in turn lead to the uptake of similar processing industries in many other countries (Love, 1987). The influence of these peripheral factors is very difficult to assess, as their importance can change significant in the course of a few years. The recent break troughs in gene-technology for instance, may have knock-on effects on the likes of plant breeders, legal issues and consumers.

Figure 2.1 Schematic representation of the EU potato industry.



Considering the complex nature of the EU potato industry the problem of quantifying the industry is obvious. If the boundaries of an industry are vague, measuring the size of the industry or its sub-sectors becomes much more difficult. Since the potato production is not regulated by the EU, only little information is centrally gathered by Brussels. Most of the EU-statistics contain only aggregated information about the potato industries of the individual member states.

To obtain a more detailed picture of the industry one has to depend on the national statistics of the member countries. The national statistical services however show a great variety in the types of information they choose to collect and disseminate about the potato industry. Definitions of the terminology used in the potato industry are not consistent through the Union. Yield for instance can mean (1) total biological production of tubers, (2) total harvested amount of tubers or (3) total salable yield of tubers. In his study of the European potato industry, Young found that in France different definitions of potato area had led to differences in the final figures of up to 27 % (Young, 1981).

In addition to the problems of definition, it must be noted that the reliability of statistical sources is not of equally high standards throughout the EU. One potato researcher even felt the need to state explicitly that "*Scientists and officials examining statistics must not discount the possibility of downright dishonesty at the source of some figures*" (MacKerron, 1992 p.72). As a result of the deficiencies in the available information the overall picture of the EU potato industry becomes easily fragmented. Nonetheless this information can serve to compile an indicative overview of the EU potato industry, its major sub-sectors and players.

2.2 Potato Production

2.2.1 Overview

Potatoes are being produced in all countries of the EU. The potential yield varies according to different climates and soil types that occur throughout Europe. The Mediterranean member states have the potential to grow two or three potato crops in one calendar year, whilst the northern countries can only grow one crop per year. The actual yields vary according to the different types of husbandry of the crop, which differ greatly throughout the EU. The actual production in any given year depends greatly on the weather during the growing season, and the planted area. The planted area tends to contract and expand according to perceived shortages or gluts in the market.

Potato production usually takes place close to the place of final consumption or utilization, because the potato is a bulky, perishable and relative low value crop, (Horton, 1987). Seed potatoes and early potatoes form an exemption to this rule, because their higher market value can compensate for the extra costs of transportation. A first look at the EU production statistics (Table 2.2) confirms this observation. The five countries (Germany, Netherlands, UK, France and Spain) that account some 75 % of the EU's potato production, also have close to 70 % of the EU's population within their territory.

Table 2.1 Potato Production ('000 t) by EU members in 1995.

Country	**Production** ('000 t)	**Area** ('000 ha)	**Yield** (t/ha)
Germany	9,438	314	30.0
Netherlands	7,340	179	41.0
UK	6,225	170	39.2
France	6,182	176	35.1
Spain	4,124	214	19.3
Italy	2,200	105	21.0
Belgium	2,106	61	34.5
Portugal	1,650	105	15.7
Denmark	1,400	46	30.4
Sweden	1,010	35	28.9
Greece	985	43	22.9
Finland	710	37	19.2
Austria	645	30	21.5
Ireland	529	22	24.0
Luxembourg	20	n.a.	30.5
EU-15	44,639	1,537	29.0

Source: ZMP 1995

The size of the average commercial potato field differs greatly throughout the EU, with countries in the northwest of the Union having potato fields of generally larger size. (see Table 2.3). For several countries the average cultivated area per farm is very low because of a very large number of farmers that only grow a small plot of potatoes (PMB, 1995).

Table 2.2 Average size of fields and number of farms producing potatoes in 1987.

Country	Size (ha)	No. (000)	Country	Size (ha)	No. (000)
Netherlands	6.73	25	Luxembourg	0.58	1
UK	5.20	34	Greece	0.55	64
Denmark	4.85	6	Ireland	0.53	52
Belgium	1.48	30	Spain	0.47	240
Germany	0.85	240	Italy	0.34	190
EU-12	*0.77*	*1,477*	Portugal	0.30	386
France	0.76	208			

Source: Eurostat, 1990.

Accurate information about the costs and revenues of potato production in the EU are also difficult to obtain. This is not only caused by a natural reluctance of producers to reveal their profits. Different accounting rules and definitions of prices that occur within countries and between countries, make a comparison difficult. The flexible exchange rates for local currencies further increases this problem. Occasionally official institutes like the EU and FAO publish price information related to potato production in selected countries. In most of these cases it is virtually impossible to trace how such prices have been collected or what type of product they actually cover. Table 2. 4 gives such a listing of different price levels throughout the EU. The reader may be advised to treat them more as indicative rather than authoritative.

Table 2.3 Average sale prices for ware potatoes in selected countries.

Country	Farm gate 1993 US $ / t	Wholesale 1994 US $ / t
Germany	121.90	131.56
Netherlands	57.03	145.79
UK	93.80	198.53
France	59.96	163.54
Spain	n.a.	220.54
Italy	213.24	271.21
Belgium	37.71	114.68
Portugal	144.27	n.a.
Denmark	137.94	184.44
Sweden	n.a.	n.a.
Greece	279.05	n.a.

Sources: European Commission 1995; FAO 1995.

2.2.2 Seed potatoes

The production of seed potatoes is of great importance to the whole of the EU potato industry. Biologically any potato can be used as a seed potato, but for commercial and modern potato production the availability of high quality seed potatoes is essential (Beukema 1990). The production of seed potatoes is different from other types of potato production because it requires a production period of between four and eight years. Furthermore only a few geographical regions have a disease pressure that is low enough to support the production of seed potatoes.

The potato crop has a very low multiplication rate, when propagated vegetatively (Beukema,1990). This means that approximately 10 % of the total potato yield and area must be set aside in order to provide the seed for the next growing season. The exact multiplication rate will vary with the quality of the starting material, the disease pressure and the type of husbandry used. In the EU the production of seed potatoes is concentrated in a few countries, from where these seed potatoes are exported to other countries (see Table 2.5) This situation is quite different in the USA, where each individual state tends to have its own seed producing industry (NPC, 1996).

Table 2.4 Area used for certified seed potato production in 1994.

Country	Percentage of EU seed area (%)	Certified seed area (ha)	Percentage of the national potato area (%)
Netherlands	32.8	37,057	20.7
Germany	16.3	18,406	5.8
UK	15.3	17,234	10.1
France	12.6	14,279	8.1
Spain	7.7	8,750	4.1
Denmark	5.0	5,630	12.2
Ireland	2.3	2,550	11.6
Sweden	2.0	2,241	6.4
Belgium	1.4	1,561	2.6
Austria	1.4	1,535	5.1
Italy	1.2	1,400	1.3
Finland	0.8	940	2.5
Greece	0.4	500	1.2
Portugal	0.4	430	0.4
Luxembourg	0.3	370	56.5
EU-15	100	112,883	7.34

Sources: ZMP 1995 & VBNA1995.

One of the main aims of the EU is the creation of an open internal market, in which goods can be moved freely and without restrictions. However this is not directly compatible with the aim to reduce the spread of harmful organisms throughout the community. In order to regulate these two conflicting interests, a common phytosanitairy certification system has been established in 1993 (Ebbels, 1993).

Planting materials such as seed potatoes may be traded freely throughout the community, as long as they are accompanied by a phytosanitary certificate, better known as a "plant passport". Plant passports are issued by the national plant health authorities, and should include information such as: the registration number of the producer, variety, tuber size, and the date of packaging. Ware potatoes, that are aimed at immediate consumption, are exempted from the need to travel with plant health passports.

Plant passports are issued according to common standards for plant health, which have been set by the newly formed plant Health Inspectorate in Brussels. This Inspectorate now supervises the activities of national plant health authorities, and offers a platform for a communal approach to contain disease such as brown rot. Import restrictions on material from non-EU countries have remained intact.

For the certification of seed potatoes the following common standards are now in force, and will eventually replace the national systems for seed classification.

EEC1	for Virus Tested Stem Cuttings (VTSC)
EEC2	for Super Elite and Elite
EEC3	for AA

EEC1 is the highest quality of seed, and only the grades EEC1 and EEC2 may be used for the production of seed potatoes. EEC3 seed may only be used for the production of ware potatoes (Meredith, 1995).

One of the problems that is not being tackled by EU legislation is the trade in uncertified seed. Although this is officially illegal, it often proves difficult to effectively put a stop to the trade in "small ware potatoes". The trade in ware potatoes is not restricted, so unless one can prove beyond any reasonable doubt that a trader is selling uncertified seed rather than truly small ware potatoes, conviction is impossible.

2.2.3 *Early potatoes*

Early potatoes are potatoes that are harvested before they are fully matured. The definition of an early potato can also be seen relative to the arrival of the maincrop potatoes. For most countries in Northwestern Europe, early potatoes are potatoes that have been harvested before 1 July, which in itself is an arbitrary criterion. Early potatoes are not essentially different from normal potatoes. Their skin set is much less developed than that of the maincrop potatoes, reflecting the time of harvesting and shorter growing period.

Early potatoes are aimed at the markets for fresh potatoes. Here they generally trade at prices well above those of potatoes from the previous maincrop harvest, which have been stored for several months, and have lost their "fresh" appeal. Mediterranean countries with two or three growing seasons for the potato, can easily harvest fresh potatoes, when the northern countries still have to start planting. Thus these countries have established themselves as market leaders in the high-value sector of early potatoes (see Table 2.6).

Farmers from northern countries can also produce early potatoes, if they produce in areas that are relatively warmer then the rest of the country (e.g. Channel Islands, south Germany) or if they are willing to invest in extra equipment such as plastic foil. In such cases the northern farmers will have to satisfy themselves with yields that are below that of the maincrop potato harvest. This is generally not a problem when the higher price per kilo results in a total revenue per hectare that is as high or higher than with maincrop potatoes.

Early potato growers from both the south and north of the EU are competing to supply the same type of consumer-markets in northwestern Europe. The farmers in the Mediterranean have the comparative advantage of a warmer climate. The farmers in the northwest can offset their higher production costs through the much lower costs of transportation to the final consumer.

Table 2.5 EU production of early potatoes.

Country	Production (000 t)	Area planted (000 ha)
Spain	677	37
Germany	509	19
France	420	22
Italy	402	23
Greece	380	14
UK	365	13
Portugal	310	15
Belgium	208	8
Ireland	64	n.a.
Luxembourg	3	n.a.
EU-total	3,338	151

Source: VBNA,1995.

2.2.4 *Starch potatoes*

Around 17 % of the EU potato production is aimed at the starch industry (see Table 2.7). The processing margins for potato starch are relatively poor in comparison to those of maize and wheat. This makes potatoes an expensive raw material for starch production (Batchelor, 1996). The use of potatoes for starch production is subsidized through the Common Agricultural Policy. The companies that produce starch from potatoes receive a refund for each tonne of (starch) potatoes that they buy, and for each tonne of starch that they produce.

The rationale for this subsidy lies in the fact that wheat farmers in the EU receive subsidies which make their produce expensive in comparison to wheat that has been produced outside the EU. This situation would put the European starch manufacturers at a disadvantage in the procurement of their raw (e.g. wheat) material for starch, compared to their competitors from outside the EU. To overcome this disadvantage, refunds are paid for every tonne of starch that is produced from raw material that is grown in the EU, which includes potatoes. Because of these subsidies the EU makes a disproportionate contribution to global production of potato starch. From the 2.5 million tonnes of potato starch that was produced in 1990, only one million was produced outside the EU, notably 300,000 t in Japan and the remaining 700,000 t in Poland, the Baltic States and Czechoslovakia (Renia,1992).

As a result of a trend towards the over production of starch and starch potatoes in the early 1990s, an EU-production quota has been set at 1.592 million ton of potato starch per year. This quota is shared between the main starch producing countries on the basis of previous production and on investments which have been made before 31 January 1994 (European Commission, 1995). The production of potato starch that exceeds the national quota, will be excluded from the production subsidies, thus causing a loss to the producers of potato starch The level of subsidies for the production of starch potatoes are likely to decline, in line with the decline of subsidies for the production of wheat. The current quota will stay in place until 1998, after which it can be extended and amended.

Table 2.6 EU starch sector in 1994.

Country	Area planted (000 ha)	Starch Potato Production (000 t)	Starch quota 1995 (000 t)
Germany	83.0	2,500	592
Netherlands	60.4	2,427	538
France	33.2	1,370	281
Denmark	24.5	800	178
Sweden	n.a.	*300*	62
Finland	n.a.	*250*	49
Austria	n.a.	*250*	46
Spain	n.a.	*10*	2
EU-total		7,897	1,748

Source: PMB 1995 , Agra Europe (No. 938, 1995).

By far the largest player in the starch potatoes is the Dutch co-operative AVEBE. With factories in the Netherlands, Germany and France, this co-operative processes the yield of around 100,000 ha. of starch potatoes per year. Its membership consists of 6,500 farmers, of whom around 4,000 are Dutch and 2,500 German. Within the

AVEBE the production and sales of starch and its derivatives are vertically integrated, which makes it a multinational concern with more than 3000 staff and an annual turnover well in excess of £ 500 million per year. About 40 % of final products are sold outside the EU (AVEBE,1993). Other large European producers of potato starch can be found in Germany and Denmark.

The interaction between the starch sector and other sectors of the European potato industry is limited. The potato varieties that are used for starch production have a high dry matter content, which is generally not acceptable for human consumption. Thus starch potatoes hardly ever end up on the markets for ware or processing potatoes. Excess potatoes from the consumption markets some times get used for the production of starch. But this option is neither preferred by the ware growers (very low prices) nor by the starch producer (low recovery rates). The seed that is needed for the planting of starch potatoes is generally grown by specialized farmers who are linked to the starch industry. Potato starch and its derivatives are used for the production of food, paper, textile, adhesives, pharmaceuticals and animal feed.

2.2.5 A brief description of the national potato industries.

Germany:

Between 1961 and 1989 the area used for potato production dropped from 976,000 ha. to 200,000, whilst the average yield increased by almost 68 %, from 22 to 37 t/ha. (ZMP, 1995). The decline in total potato production was largely caused by ending the practice of using potatoes for cattle feed. The re-unification with Eastern Germany in 1990 led to an increase of 200,000 ha. of potato land with an average yield of only 20 t/ha. Integration of the two potato industries is still ongoing and it is expected that the current average yield of 30 t/ha will continue to rise, and thus cause further reductions in the planted area.

The fact that Germany accounts for just over one fifth of the total EU potato production is not surprising considering the fact that it also accounts for one fifth of the EU population. Although potatoes are grown in all of the German bundeslander, Lower Saxony (120,000 ha), Bavaria (62,000 ha) and Nordrhein-Westfalia (31,000 ha) are the most important ones. Information about the German potato industry is available from annual reviews by the Zentrale Markt Preisstelle (ZMP,1996) and occasionally publications by others such as French (1980), Young, (1981) and Garbut (1987).

The Netherlands:

The volume of potato production in the Netherlands is disproportionate to the size of its population, i.e. the domestic demand. It can only justify this enormous production because of large domestic industries for starch and processing, combined with a leading position in the export of seed and ware potatoes as well as potato products and potato starch. The Dutch potato industry is generally regarded as highly advanced, and as such has been studied by various authors such as Warren (1986), Van der Zaag (1990) , Collins (1989) and Renia (1992).

The United Kingdom:

Potato production in the UK is modern, which is expressed by the fact that the average yield is the second highest in the EU. The production of seed is concentrated in Scotland (Young, 1990), whilst a large portion of the ware production takes place in the east of England. From 1933 until 1996 the production of potatoes in Great Britain has been regulated by a regulatory system of area-quota's and intervention prices. From 1996 onwards the production of potatoes will occur without any form of price or area regulation. The UK potato industry is well documented, most notably by the publications of the Potato Marketing Board in Oxford.

France:

The French potato industry is among the four highest performing in the EU, in terms of total production and yield per hectare. Almost 70 % of the national potato production takes place in a few regions north of Paris; Bassin-Parisien, Haute Normandy, Nord, Pas-de-Calais and Picardie (Mackerron,1992). In this regions there are many large and highly professional potato growers, who are organized in powerful cooperatives (Reuvers, 1995). The remaining 30 % of the potato production is done by a large number (nearly half a million according to Garbutt, 1987), of small farmers who are spread throughout the country. The production of seed potatoes is concentrated in Brittany, the North East and Central Massif (Henderson, 1977).

Spain:

Information about the Spanish potato sector is notoriously difficult to obtain and difficult to verify (Ennew, 1993). A striking feature of the Spanish industry is the difference between large farmers and small farmers. A survey in 1971 showed that 0.2 % of the potato producing farms (approx. 5,000) cultivated more than 1,000 ha. each, and accounted for more than 25 % of the total area. At the same time 25 % of the potato producers (632,000) grew less than one ha. of potatoes and accounted for no more than 0.6 % of the total area (MacKerron,1992). About half the Spanish potato area is located in the Northwest of the country, with Alava being the center for seed potato production. The southern part of the country is most suitable for the production of early potatoes, especially for exports (Norman, 1989). Potato production also plays an important role on the Canary Islands (Baker, 1982).

Belgium:

Like neighboring Holland, Belgium has a very modern potato industry, that is also closely intertwined with the Dutch. Two thirds of Belgian potato production takes place in the Dutch speaking region of Flanders, which doesn't stretch more than 80 miles from the Dutch border. The destination of the ware crop is equally divided between (a) domestic fresh consumption, (b) exports and (c) the processing industry. Most of the exports are destined for the Netherlands to supply their processing industry, whilst foreign companies (Farm Frites, McCain, United Biscuit's) own the bulk of the processing facilities (Cools, 1994).

Portugal:

This is one of the poorest countries of the EU, and its agriculture is dominated by small-scale family farms with average size of only 2.5 ha. These are often further split up into fields of 0.5 ha. or less. Potato production is concentrated around the northern the city of Oporto, and in the middle of the country, which are regions where the rainfall is the highest (Ramsbottom,1984). The small scale of production is problematic for the larger customers such as crisp-manufacturers and supermarkets, who demand a continuous and uniform quality. Thus it seems inevitable that in the next decade much of the potato production will be concentrated on larger farms, producing exclusively for supermarkets, export and processors (Delft,1995). Expansion of the area under cultivation is most likely to take place in the region to the south of Lisbon, mainly for the production of early potatoes for export to northern Europe (Hesen,1995). The low yields in Portugal are caused by a combination of high disease pressure, water shortages and little mechanization. The Portuguese processing industry currently consists of only two factories for the production of potato crisps, which are owned by PepsiCo and United Biscuit's. Because a lot of the domestic production does not meet the quality standards of the crispers, Portugal imports between 100,000 to 150,000 tonnes of ware potatoes per year. mainly from France (Hesen,1995). Traditionally seed potato production takes place in the mountainous northeast of Portugal. More recently the country is producing mini-tubers in a central laboratory. These mini-tubers are than multiplied on the Azores islands, which are located several hundred miles westwards into the Atlantic Ocean, transported back to the Northeast of Portugal for further multiplication (Hesen,1995). The yields for seed potato production lie higher (18 t/ha) than the national average, since many of these fields are being irrigated (Delft, 1995).

Greece:

The Greek potato industry has three growing seasons; a spring crop (mainly produced in the south and eastern parts of the mainland and south and eastern islands), a summer crop (produced in the north of the country) and an autumn crop (produced in the same regions as the spring crop (Doumas, 1992). In terms of planted area the summer crop accounts for 40 % of the total, and the spring and autumn crop for 30% each. Although around 25 % of the agricultural land is irrigated, it often happens that water is not available when most needed. Thus drought-related problems often reduce the yields. Generally the producers are not very well organized with respect to collective purchasing of seed or marketing of the fresh produce. Most of the Greek potato crop is used for domestic human consumption. The processing industry is still in its early stages of development. Exports of early potatoes to the UK, Netherlands and Germany are of great importance for the Greek potato industry (Varnham,1981).

Ireland:

After Luxembourg, the Republic of Ireland is the smallest producer of potatoes in the EU, with an area of just over 22,000 ha. This situation was significantly different before the great famine of 1845, when potato production occupied an area of 2.2 million ha. and resulted in an annual production of 14 million t. Nowadays half the potato crop is produced with in a radius of 50 miles from the capital Dublin, with county Meath being the dominant region. The production of early potatoes is centered around the city of Cork in the southeast of Ireland (Abel,1995). Unlike the UK and many other parts of Europe, the yields in Ireland have not increased significantly over the past few decades. This is largely attributed to the great number of smaller growers, whose cultivation techniques have not been modernized (Ennew, 1993). The Irish processing industry is lagging behind the rapidly growing domestic demand. Annual imports of frozen potato products are around 40,000 t per year (Abel, 1995).

Luxembourg:

Potato production in Luxembourg occupies an area of less than 1000 ha, and around half this area is used for the production of seed potatoes. Economically Luxembourg is deeply intertwined with Belgium, and for practical purposes its potato industry can be considered to be part of the Belgian one.

Italy:

Although potatoes are grown throughout the whole of Italy, almost 40 % of the production takes place in the regions of Lazio, Campania and Abruzzi-Molise (Mackerron,1992). The production of early potatoes is concentrated in the south of the country, and the multiplication of seed potatoes in the north of the country (Young, 1981). Italy is a large importer of seed and ware potatoes, and exporter of early potatoes (Young, 1981).

Denmark:

The Danish potato industry is characterized by a large starch processing sector, which accounts for more than half of the total potato area and production (SAC, 1995). Denmark also devotes a large portion (more than 12 %) of its potato area to the production of seed potatoes (ZMP,1995). The size of the seed area is justified because of the countries high planting rate, disease pressure and exports to overseas markets. Potato production is largely concentrated on the Jutland peninsula, and especially around the area of Ringkobing in West Jutland (Young, 1981).

Austria, Finland and Sweden:

The potato industries of these three new member states of the EU are not well documented. The most likely reasons lie in the fact that these individual industries belong to the smallest in Europe. Their combined potato area accounts for only 7 % of the total EU area, and in terms of production they barely account for more than 5% of the EU total (ZMP, 1995). None of these countries are likely to be capable of having a significant influence on the whole of the EU-potato industry. So far only Finland has made an attempt to increase its export of seed potatoes to the other EU member states (Mossman, 1996).

2.3 Potato Consumption

The role of the potato as an important source of human nutrition has been well established and reviewed (e.g. Woolfe, 1986). Since the second world war the per capita consumption of potatoes has fallen steadily in the countries that now make up the EU. Nevertheless the average EU consumption of around 80 kg/head is markedly higher than the 55 kg in North America, or the world average of 33 kg (Horton, 1987).

Within the EU the consumption levels of potatoes differ greatly. The Portuguese and Irish consume almost double the EU-average, whilst the Italians consume only half that amount. (see Table 2.8). The differences in the levels of consumption can be explained by different eating habits in these countries, different levels of purchasing power and the availability of other staple crops.

Between the countries of the EU there is also a great variety in the preferences towards the characteristics of the "ideal" potato and the way in which it is consumed. In the Netherlands alone more than 110 different potato varieties are grown to cater for the needs of domestic and overseas customers (NIVAA, 1994). Although each country may have only a dozen varieties that supply the bulk of the ware potatoes, there many niche markets which can have substantial rewards. In April 1996 the harvest of Bonotte, a French delicatessen variety, was sold at a record price of £ 335 per kilo (Aardappelwereld, 1996).

Table 2.7 EU consumption of potatoes, including processed products (kg/head/year).

Country	**1987/88**	**1990/91**	**1993/94**
Portugal	107.1	137.0	153.0
Ireland	141.6	149.8	148.5
UK	141.6	98.8	110.0
Spain	106.3	106.3	106.0
Belgium/Luxemb.	97.0	96.9	99.0
Netherlands	87.3	86.6	86.5
Greece	81.2	88.5	85.0
Sweden	83.6*	83.6	83.0
EU-15-mean	*n.a.*	*79.1*	*81.7*
France	74.4	71.1	74.5
Germany	71.6	75.0	73.3
Austria	61.8*	61.4	60.5
Finland	65.7*	63.5	59.2
Denmark	64.3	56.9	55.0
Italy	38.3	38.7	41.5

* 1988/89

Sources: ZMP,1992 and,1995.

European potato consumers and processors also have clear preferences for the size and shape of the potatoes they purchase. The size of the potatoes can lead to a price differential on a per kilo basis, of 200 % or more (Askew, 1996). Consumers also have different preferences throughout the growing season, which cause early, or "out-of season" potatoes to trade at a price premium. Furthermore there is a growing demand on the method by which the potatoes have been grown. For example the organically produced potatoes are sold at markedly higher prices (Spiertz, et al., 1996).

Table 2.8 EU preferences for fresh potatoes.

Country	Skin color	Flesh color	Flesh texture	Shape	Uses	Main Varieties
Germany	yellow, some red	yellow	waxy	long/ oval	boiling, mashing, baking, dumplings, chipping	Bintje, Desiree, Linda, Cilena, Hansa, Sieglinde, Roxy, granola, Nicola, Hela, Grata, Estima, Wilja, Marfona, Pentland Dell, Romano, Morene, Priemiere
France	yellow, white and red; clear and bright	yellow or white	waxy	long/ oval	chipping, boiling, salads, mashing	Bintje, Mona Lisa, Nicola, Estima, Nadine, Wilja, Pentland Dell, Maris Piper, Marfona, Pentland Squire, salad varieties like Charlotte, Roseval
Italy	white, clear & bright, some red	yellow	waxy	long/ oval	boiling, chipping, mashing, gnocchi	Bintje, Nicola, Mona Lisa, Mondial, Desiree, Kennebec, Wilja, Estima, Maris Piper,
Netherlands	yellow, some red	yellow	waxy, moderately waxy and floury	long/ oval	boiling, chipping	Bintje, Agria, Sante, Eigenheimer, Dore, Nicola, Estima, Pentland Dell,
Belgium	yellow, some red	yellow	waxy, moderately waxy	long/ oval	Chipping, sauteeing, boiling, salads	Bintje, Charlotte, Rosa, Nicola, Maris Piper, Pentland dell, estima, Wilja, Nadine, Premiere
Finland	yellow	yellow	floury, waxy	long/ oval	boiling, baking, salads, stews	Bintje, Nicola, Hetha, Sabina, Mathilda, Rosemunda, Rocket, King Edward

Country	Skin colour	Flesh colour	Flesh texture	Shape	Uses	Main Varieties
Portugal	red, some yellow	white , yellow	medium waxy	long/ oval	chipping, boiling, stews, roasting, mashing	Jaerla, Kennebec, Desiree, Romano, Estima, Wilja
Demark	yellow	yellow	floury, waxy	oval	chipping, boiling, mashing	Bintje, Saba, Hansa, Folwa, Posmo, Kennebec, Nicola, Oleva, Spunta, Estima, Maris Piper, Cara, Wilja, Desiree, Saturna
Ireland	red, parti-coloured and white	white	floury	round/ oval long/ oval	chipping, boiling, mashing	Kerr's Pink, Record, Golden Wonder, Pentland Dell, Home grown, Rooster, Fianna, Marid bard, Maris Piper, Record, Premiere
UK	yellow, red	white	waxy, floury	round/oval long oval	chipping, boiling, baking, mashing	Maris Piper, Estima, Pentland Dell, Cara, Wilja
Spain	white, yellow, red	white	medium waxy	long/ oval	chipping, boiling, stews, salads, tortilla	Bintje, Mona Lisa, Spunta, Kennebec, Red Pontiac, Agria, Estima, Nadine, Cara
Greece	yellow	white, yellow	medium waxy	long/ oval	chipping, boiling, sauteeing	Bintje, Agria, Spunta, Diamant, Jaerla, Liseta, Kennebec, Marfona, Estima, Nadine
Austria	yellow, some red	yellow	waxy	oval	chipping, mashing, boiling, salad	Bintje, Sieglinde, Nicola, Jaerla, Linzer delikatess, Linzer Rose, Maris Piper, saturna, Agria
Sweden	white, part-coloured	white, yellow	waxy, fluffy	round/ oval	boiling, baking	Bintje, King Edward, Cara, Estima, Maris Piper, Premiere

Source: PMB, 1996 b

Taking the above stated observations into account, the EU consumers market for potatoes can be subdivided according to; varieties, size and shapes, month of harvesting and method of production. Thus it can be safely concluded that the number of niche markets must be several hundreds. This conclusion partly explains why it is difficult to collect adequate and comparable information about the consumption side of potatoes.

An increasing portion of the EU-potato consumption is taking place in processed form. This follows a trend from North America, where already more than half the consumption takes place in the form of processed products (Sieczka, 1992). The main types of products are frozen French fries, crisps, par-fried potatoes and dehydrated potato products like mashed potatoes.

The processing of potatoes is concentrated in a few countries, with only five countries accounting for 95 % of total EU-production. (see Table 2.10). This situation can be partly attributed to the fact that almost 60 % of the EU population (i.e. consumers) live in these countries. Other factors are the ample supplies of raw material throughout the season, and relative low costs of potato production. Many of the countries with a large processing industry are exporting their products to other countries in the EU and elsewhere. Countries with a smaller processing industry often concentrate on the production of crisps. This is because the transport costs per kilo for crisps are considerably higher than for frozen French fries.

Table 2.9 Intake of fresh potatoes by the processing industry ('000 t).

Country	1988	1991	1994
Netherlands	1,723	1,969	2,498
UK	1,439	1,573	1,814
Germany	1,267	1,850	1,720
France	730	916	967
Belgium/Luxemb.	400	555	867
Italy	240	270	270
Ireland		60	60
Spain		45	45
Denmark	30	30	30
Portugal			25
EU-total	5,829	7,268	8,271

Source, VBNA, Hesen,1995.

Ownership of the processing facilities is largely concentrated in the hands of a few multinational companies. Europe's largest potato processor is the Dutch company AVIKO which has an annual intake of fresh potatoes that is well in excess of one million t. The Canadian company McCain is Europe's second largest potato processor, followed by Farm Frites (Dutch) and PepsiCo Food International (USA). Because of the very competitive nature of the processing industry, it is very difficult to obtain first hand-data about the processing capacities and market shares of these companies. Other companies that also play a significant role in the European processing sector include United Biscuits, Nestle, Unilever and Procter & Gamble.

2.4 Potato trade

The EU is self sufficient in its needs for potatoes and potato products (European Commission 1994). The trade with countries outside the EU mainly concerns high value products such as seed potatoes (net exporter), early potatoes (net importer) and processed potatoes (net exporter) The trade volume of potatoes in the EU varies between ca. 13 and 17 % of the annual production (European Commission, 1996). Most of this trade takes place between the countries of the EU. Countries of the Mediterranean and the rest of Europe account for most of the remaining trading volume.

It has always been difficult to obtain a clear picture of the volume and values of the internal potato trade. The exporters and traders have a natural tendency to keep these figures close to their chest. The ending of the internal border controls, in January 1993 has made it even more difficult to establish the intra-EU trade flows. Until 1992 domestic customs officers used to keep records of volumes and presumed values of the trade between countries.

2.4.1 Seed potatoes

The world trade in seed potatoes is dominated by the Netherlands, which has an estimated market share of between 50 % and 66 %. Annually the Dutch export 600,000 t or more of seed potatoes, which is equal to 70 - 75 % of total Dutch seed potato production (Renia, 1992). Most of the exports go to countries in Europe and North Africa. Three Dutch companies (Agrico, ZPC , Hettema) carry out 90 % of the total export of Dutch seed potatoes.

Other countries with a sizable seed potato export are the UK, Germany, France and Denmark. But as demonstrated in Table 2..11, their trading volume is less than a tenth of that of the Netherlands.

Table 2.10 Seed potato trade 1994/95 (t).

	Exporter		
Importers	**Netherlands**	**UK**	**Germany**
Austria			1,326
Belgium	45,854	76	171
Denmark	1,406	123	74
France	61,001	250	2,694
Finland	507		
Germany	75,240		
Greece	23,555	842	209
Ireland	327	1,362	
Italy	86,263	971	794
Netherlands		1,162	1,365
Luxembourg	448		
Portugal	42,674	1,931	2,794
Spain	55,283	5,955	2,673
Sweden	2,919		
UK	45,275		165
Total EU	440,752	12,672	12,265
Other Europe	28,313	4,664	1,563
Non-EU	267,149	24,411	12,693
World-total	**736,241**	**41,747**	**26,521**

Sources: ZMP 1995; PMB 1995; VBNA 1995.

2.4.2 Early and maincrop ware potatoes

The EU is a net importer of early potatoes from countries such as Cyprus, Egypt, and Malta. The net imports vary between 360,000 t and 470,000 t per year, and show an increasing trend since the middle of the eighties . In 1993 The UK (37 %), France (22%) Belgium (17 %) and Germany (13 %) accounted for most of the non-EU imports of early potatoes (Savvides, 1994). The Mediterranean countries of the EU also export a lot of early potatoes to the north of the Union. Statistics on this trade are difficult to obtain, since the published data is mostly an aggregate of early and maincrop trade.

Statistics about the intra-EU trade in ware potatoes (both maincrop and early) are easily blurred by countries that import potatoes for the sole purpose of re-exporting them again. It is a well known fact for instance that Belgian ware potatoes are transported to Holland, from were they are being exported to Germany with a price premium, because "Dutch" potatoes have a better quality image (Collins, 1989). Table 2. 12 gives an overview of the five largest exporters of ware potatoes in the EU.

Table 2.11 Exports of early and ware potatoes 1994/95 (t).

	Exported by:		
Imported by:	**Netherlands**	**Germany***	**UK**
Austria		6,477	
Belgium	242,106	18,009	10,581
Denmark		12,560	2,254
France	29,078		6,650
Finland			
Germany	483,262		5,401
Greece	2,062		612
Ireland	3,069		36,213
Italy	68,929	50,741	3,626
Netherlands		260,764	36,793
Luxembourg			
Portugal	12765		3,704
Spain	40442	3,723	55,592
Sweden	14,024	11,330	10,024
UK	62,165		
Total EU	957,902	363,604	171,450
Other Europe	32,375	12,778	42,846
World-total	**1,053,997**	**391,075**	**222,475**

* excluding 401,199 t starch potatoes to the Netherlands.

Source, VBNA1995, PMB1995. ZMP1995, Cools 1994,

2.4.3 Processed products

The exports of processed products is limited to countries which have a strong domestic processing industry. The bulk of the exports are destined for other EU countries. Due to the high costs of (frozen) transport the exports of processed products outwith the EU is limited to areas such as Japan and the middle east, where the customers can pay a significant price premium. The Netherlands is the EU's largest exporter of potato products, probably followed by Belgium.

Table 2.12 Dutch and UK exports of potato products 1994/95.

Country	Netherlands t of products	UK * t of raw equivalent
Austria	n.a.	n.a.
Belgium/Lux.	68,400	1,881
Denmark	20,000	1,922
France	111,500	6,465
Finland	n.a.	n.a.
Germany	226,200	3,441
Greece	25,300	1,626
Ireland	43,700	26,813
Italy	82,400	4,328
Netherlands	-----	7,222
Portugal	9,900	527
Spain	50,400	7,132
Sweden	n.a.	n.a.
UK	219,300	-----
EU **Total**	**933,700 ton**	**78,556**

* Conversion factors used by PMB: crisping 4:1, dehydrated 6.2: 1 , frozen 1.9; 1

Source: VBNA 1995, PMB1995.

2.5 Current developments in the Industry

The potato industry is dynamic and subject to the changing demands of its customers and the economic environment. The following developments are likely to lead to important changes in the current structure of the EU-potato industry.

2.5.1 Organic potatoes

One of the major areas of change in the EU potato industry for the next decade will be the response to the consumers demand for potatoes produced by environmentally friendly methods (Spiertz, et al, 1996). Consumers in many parts of the EU are becoming averse to consuming potatoes that has been extensively treated by chemicals. Thus there is now a growing market for "organically" produced vegetables (Unwin, 1995) This covers a wide range from products that have had no chemical treatment, to products that have only received marginally less chemicals. The willingness of consumers to pay a premium price for such potatoes varies greatly. There is a lot of discussion going on within the potato industry as to how many chemicals and sprays can be tolerated in the process of potato production and storage.

2.5.2 Biotechnology

Compared to other plants, it is relatively easy to place genetically modified material into the potato crop. Therefore the potato has often been used as a model plant to test new transgenic technologies. As a result of this the potato will be one of the first crops for which transgenetic material becomes available (Bijman, 1993). In 1996 already more than 4,000 ha. of transgenic potatoes were grown in the USA. These potatoes have been equipped with a gene that make them resistant to the Colorado beetle (Potato Review, 1996). The advantage of these transgenic potatoes is the lower doses of chemicals that are needed to achieve a commercial yield. Opinions about the advantages and disadvantages differ greatly throughout the EU. At the time of writing field trials with transgenic potatoes were being conducted in a number of European countries, but the material is not yet allowed to enter the food chain.

2.5.3 Rapid multiplication of seed

The traditional clonal seed multiplication system is perceived as being slow, troublesome and expensive. The time between the release of a new variety and the availability of commercial quantities of seed tubers can be as much as six or eight years. This means that when a breeder sets out to meet a market demand by breeding a new variety, it can easily take a decade and a half before the resulting variety arrives on the commercial potato markets. During this period the market demands may have changed, and the slow multiplication's causes a long exposure to potato diseases. Four different types of technology that aim to improve the multiplication rate of potatoes are currently being investigated. They are mini-tubers (Lommen, 1995), micro-tubers (Haverkort, 1991) TPS (Almekinders, 1996) and aerial stem-tubers (Percival, 1996). Up to date only the use of mini-tubers has seen a commercial uptake in the EU.

2.5.4 The EU potato regime

At present the potato crop (with the exception of starch potatoes) is not regulated by the Common Agricultural Policy (CAP). Plans have been drafted and discussed, about the establishment of a European potato regime over the last couple of years. (Ennew,1993). Member states are divided on this issue, with countries like Greece, Spain, France, Italy , Portugal and Ireland in favor of a market regulating body, and Belgium, Germany, Luxembourg and the Netherlands against. The latest plans are based around the following six objectives:

1 Uniform plant health legislation
2 Registration of commercial growers
3 Elimination of national state aids to potato growers
4 Elimination of trade restrictions
5 Development of quality standards and grades
6 Limited funding for market development schemes

Source: (SAC, 1995)

It is uncertain whether a potato regime will be set up in the next few years, if it will be set up at all. In 1996 the Irish Minister for Agriculture, who held the chairmanship of the failed to win support for his proposal to introduce a lightweight potato regime for the EU. European experiences with agricultural -quota have not always been positive in terms of their cost of operation and actual effect (butter, wine and olive mountains). The debate about a common potato regime is likely to revive when large potato producing countries from eastern Europe are to join the common market.

2.5.5 EU enlargement

A great number of countries are seeking membership of the EU. They include Cyprus, Malta, Turkey and most countries of the former Eastern bloc. The effect of small countries like Cyprus and Malta will be limited, since their potato industries are relatively small and already largely integrated with the rest of the EU industry.

The impact of opening the EU-markets to countries from Central and Eastern Europe, will be much more significant. The potato industry of Poland, has an area that is larger than that of the EU-15 combined, with the realistic potential to double its current average yield of only 17 t/ ha. With the right infrastructure put in place. Poland could theoretically replace all the potato production that currently takes place in the EU. Arguably Poland would need to implement a comprehensive strategy to improve the quality of its performance (SAC,1995), but with high unemployment and very low wages compared to the standards in western Europe, the production costs are likely to remain substantially lower for many years to come. Negotiations about the extension of the EU to the east are likely to take several years. One of the main problems is the unifying of agricultural and labor markets. The countries of the EU are ambiguous about their relations with the countries from the former communist bloc. On the one hand they enjoy the end to the cold war era and its related problems, on the other hand they fear to have to pick up the bill for restructuring these neighboring economies, whilst many of their own economies are also in need of extra help.

2.5.6 The Common Plant Variety list

Since April 1995 the registration of plant variety rights has been unified under new EU-legislation. Previously breeders had to register their varieties separately with the national authorities of each member state. This system was not only troublesome, but also confusing since the same variety could be registered under different names in different countries. Under the new regulations breeders submit their applications only once, directly to the Community Plant Variety Office (CPVO) in Brussels. The CPVO will then organize the necessary field trials in two or more EU countries, and decide whether to place the candidate on the Community Plant Variety List.

Once a variety is registered on this list, it may be used (under agreement with the breeder) throughout the EU. The existing varieties that previously have been granted plant variety rights can be placed on the Community Plant Variety List, provided that they meet certain criteria. In addition to royalties on the production of certified seed, breeders will from 1997 onwards also be able to claim (lower) royalties from farmers who used home-saved seed. This is especially important for the potato crop, since it is very easy to produce home-saved seed potatoes. The financial effects of this regulation will be small in the near future, since only newly registered varieties can claim royalties on home saved seed.

2.6 Conclusions

The EU potato industry is large and plays an important role in European agriculture. Due to its high average yield (29.5 t/ha) it only utilizes some 8 to 9 % of the world potato growing area to generate 16 % of the global potato production. The annual production is approximately 44 million ton, with a farm gate value of more than 5 billion ECU. The EU is as a whole is self sufficient in its needs for potatoes and potato products The trade with countries outside the EU mainly concerns high value products such as seed potatoes (net exporter), early potatoes (net importer) and processed potatoes (net exporter).

Potatoes are being produced in all countries of the EU, but Germany, the Netherlands, UK, France and Spain account for almost 75 % of the total production. Approximately 17 % of the EU production is aimed at the starch industry which is subsidized by the EU. The EU consumers market for potatoes can be subdivided according to; varieties, size and shapes, month of harvesting and method of production. These differences create a large number of niche markets.

EU production of seed potatoes is largely concentrated within a few countries, from where these seed potatoes are exported to other countries. Seed potatoes may be traded freely throughout the community, as long as they are accompanied by a phytosanitary certificate, that is better known as a "plant passport". There are three classes of seed potatoes : EEC1 , EEC2, EEC3, with EEC1 being having the highest quality. The trade in seed potatoes is dominated by the Netherlands, which has an estimated share of between 50 % and 66 % of the global seed potato trade. The trading volume of the second largest seed exporting country is no more than 10 % of the Dutch volume.

USA-style TPS technology offers the prospect to many countries of the EU to become self sufficient in the production high quality seed potato tubers, and also to reduce the overall cost of potato production. Consequentially the countries that currently export large quantities of seed potatoes, can expect a decrease in demand. The use of USA-style TPS technology is also expected to cause a decrease in the use of low quality uncertified seed tubers, and subsequently lead to a reduction in the usage of agricultural chemicals.

3. TRUE POTATO SEED TECHNOLOGY[1]

3.1 Introduction

This chapter reviews some of the main aspects of TPS technology namely; the physiology and production of seed (3.2), the breeding (3.3) the agronomy (3.4) its history (3.5) and especially the recent developments related to USA-style TPS technology[2] (3.6).

The potato crop can be propagated in two ways; vegetatively (clonal) and sexually. Hawkes (1992) concluded that the vegetative way of propagation is less successful under wild conditions especially when high competition exists with other plants. Under stable environmental conditions however, vegetative propagation is found to be more successful, and commercial potato production throughout the world is almost completely based on vegetative propagation. Tubers from the potato are easily planted and produce new plants that have the identical genotype of the parent plant. In this way once the "ideal" potato is identified, it can be reproduced indefinitely by means of the vegetative system.

In contrast to the vegetative system, True Potato Seed (TPS) technology is based on the sexual reproduction mechanism of the potato. The “True” refers to the fact that the sexual multiplication system uses the botanical (i.e. true) seeds of the potato plant. In contrast to this, the vegetative multiplication system uses "seed potatoes" that are not actually seeds, but ordinary tubers from the potato plant. The vegetative propagation of potatoes has a successful track record over many of years and millions of hectares. However the vegetative multiplication system is not without problems

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[1] This chapter includes some material that has been earlier presented in the article "The current status of TPS technology in the World" by C.J.M. Almekinders, A.Chilver and H.M. Renia, as Published in Potato Research (1996) Vol 39 (3) p 289-303.

[2] USA-style TPS technology is defined as the use of botanical potato seed, of potato hybrids that have been bred in the USA, for the production of high quality and seed potato tubers. It also implies the direct seeding of the botanical seed is into the open field, and the expectation of commercial yields from the seedling tubers that are equal to those of commercially available clonal potato varieties, as well as tuber characteristics that are capable to meet the quality standards of industrialized countries

(e.g. disease transmission, bulkiness, slow multiplication and perishability of the seed tubers). In order to improve the provision of potato planting material there is ongoing research to develop new ways of vegetative multiplication as well as sexual multiplication.

TPS technology[1] offers the following advantages over vegetative propagation system;

1 *Reduced transmission of viruses and diseases*: Several hundreds of viruses and diseases can be transmitted through clonal seed, whilst this is reduced to only a handful with true seed. By eliminating these diseases from the parent population, absolute disease free planting material for the potato crop becomes available (Umearus,1987).

2 *Higher multiplication rates*: The sexual propagation of potatoes has a multiplication factor in the order of 1: 2000, as opposed to 1: 10 with clonal seed. (Santos Rojas et al., 1996). Thus it is possible to replace existing stock and bring through newly bred varieties much faster into the mainstream of potato production than is currently possible.

3 *Pest and rot resistance*: During storage, seed tubers can easily perish due to the influence of common pests such as diseases and rodents. Unless expensive cold storage facilities are available, considerable storage losses will occur in the stock of seed potatoes. The volume and weight properties of TPS make it very easy to prevent such storage losses. A glass jar or aluminum bag will suffice to protect the TPS.

4 *Low transport costs*: The planting of one hectare of potatoes with TPS requires

[1] The advantages and disadvantages mentioned relate to all the forms of TPS technology (direct seeding, transplanting and nursery production).

only a few hundred grams of seed, which is considerably less than the 2,000 to 3,000 kg of seed potatoes that are commonly used at present. Because of the lower weight and volume, dramatic reductions in storage and transport costs can be realized.

5 *Price reduction*: The use of seed potatoes can account for more than 50 % of the production costs of potatoes. Depending upon the economic price of inputs, true potato seed can be produced much more cheaply than clonal seed, and thus reduce the overall production costs for potatoes (Bedewy, 1996b).

6 *Import substitutions*: Especially in developing countries with hot climates, most imports of vegetative seed potatoes originate from temperate (western) countries which can result in a considerable outflow of (hard) currency. The use of TPS can significantly reduce a country's the dependency on foreign suppliers, and thus reduce the outflow of hard currencies.

7 *Improved disease resistance*: Because a potato field grown from TPS is in actual fact a diverse genetic population, its overall disease resistance will be better than that of a clonal potato field, which consists of only one genotype. (CIP, 1987).

8 *Greatly improved storage characteristics*: The amount of TPS that is required to plant several hectares can easily and inexpensively be stored in a glass jar or aluminum foil bag at room temperature for several years without losing its potential to produce a healthy crop. Storage of seed tubers to plant the same area requires an expensive storage building where diseases and micro climate have to be controlled. Even under good storage conditions, potato tubers can not be kept viable for a period of more than a year.

The use of TPS technology has the following disadvantages when compared to the vegetative multiplication system

1 Establishment of a vigorous potato crop from TPS is significantly more difficult than from potato tubers. Adverse conditions (rain, drought, wind, fertilizer) during the first six weeks after seeding have a much greater impact on the seedlings than on the plants that emerge from potato tubers. Hence it requires more time of skilled labor.

2 The tuber yields from the seeding of TPS will generally be lower than that of tuber plantings.

3 Variations in the emergence and maturity of a potato crop grown from TPS may occur, which may hinder the uniform appliance of cultural practices (e.g. hilling up of the plantlets, vine killing, harvesting).

4 Tubers of TPS-varieties may be less uniform in skin color, flesh color and shape, than clonal varieties.

5 The current certification systems are not yet able to certify crops grown from TPS varieties, since they do not meet the DUS (Distinctiveness, Uniformity , Stability) standards that have been set up especially for clonal varieties. Hence the grower that uses TPS technology to produce seed potato tubers that are of superior quality, will be unable to have it certified as "seed tubers" and claim the price premium for his higher quality.

The utilization of TPS technology requires a partial overhaul of the existing system of potato production, with a new approach from breeders, seed suppliers and potato producers alike.

3.2 Physiology and production of seed

Seed physiology

TPS technology is based on the natural ability of the potato to produce flowers, which are then fertilized and set berries that contain potato seeds. The process of seed development on the potato plant (see Table 3.1) is very similar to that of other members of the genus *Solanum*, such as the tomato, egg-plant and chili peppers. Elaborate descriptions on the processes of sexual fertilization of the potato are made by various authors, one of the most notable by Cutter (1992). For the purpose of this study, attention is concentrated to those aspects of potato seed that are considered important from an economic point of view.

Overview of sexual propagation process of the potato

Time (days)	Activity
0	Flowers open on potato plants that are grown from either seed tubers or true seed. (The number of flowers and time of opening depends on genotype and environment)
+1 to 2	Flowers are pollinated, by own or other pollen
+ 1	Pollen germinate within the flower
+ 2	Pollen fertilize the ovules
+ 2 to 4	First signs of fruit set become visible
+ 40	Seed formation is ready, berries can be harvested

Source: White, 1983

In order to maximize the production of TPS per hectare, it is important to bring the production of berries and flowers per plant to a high level. Unfortunately most of the potato varieties currently cultivated do not produce flowers under normal field conditions, and even the varieties that do blossom don't always produce full-grown berries. The fact that many commercial varieties do not blossom is a side effect of breeding strategies that were aimed at other characteristics of the potato (Umearus, 1987). Flowering and berry production can be limited both by genetic factors of the parent plants as well as by adverse environmental conditions. To optimize the production of seed, it is necessary to use different parental lines (see 3.3) in a conducive environment.

Flowering

Early research on the production of seed (Clarke et al, 1939, 1942) showed that day length has a positive effect on the setting of flowers with potatoes; increased daylight resulted in more flowers and berries being produced per plant. A photo period of 16 hours per day stimulates most varieties to produce a sufficient amount of flowers and berries for breeding purposes. Furthermore it is known from other literature (Cutter,1992) that low night temperatures have an adverse effect on the production of flowers and berries. Almekinders (1992) concluded that seed production in the warm tropics is seriously limited by a combination of short days and high temperature. Additionally it has been suggested that the quality of seed produced under high temperatures is less because of its lower weight and size. (Almekinders et al., 1991). Increased stem density can increase flower production per square meter and the proportion of flowers that are being formed at the beginning of the growing season (Almekinders, 1993).

In temperate climates the problems that reduce the flowering of the potato can be largely overcome by the use of several harmless techniques. McClean and Stevensen (1952) described three ways to overcome this problem with a potato variety like Russet Burbank, which normally does not produce botanical seed;

a) the use of mechanical girdling
b) the growing of cut stems with flowers within a nutrient solution
c) R*hizoctonia* girdling.

The first two ways proved to be the better, as they lengthen the period in which pollination and fertilization can occur. The use of the nutrient solution resulted in 2-4 berries with between 115 and 125 seeds per berry.

Patterson (1953) described yet another successful method of inducing flower set and berry production with Russet Burbank and similar varieties. He obtained increased berry setting of around 125 seeds per berry, by growing parent plants indoors and by reducing the temperature as soon as the flower-buds appeared. This method has been used since 1944 by the Department of Horticulture, University of Saskatchewan, Canada.

Pollination

Successful inducement to flowering does not automatically mean that the flower will be pollinated and produce berries. The potato flower has to be pollinated by pollen from either the same plant and variety (open pollination) or by pollen from another variety (cross pollination). Apart from the actual pollination, the further processes of fertilization, seed set etc., are identical for both self pollination and cross pollination.

Open pollination (op) , also known as self pollination, does not require much labor from mankind, since the process is essentially natural. Cross pollination or hybridization however requires a great amount of skilled and dedicated labor. Because of the labor aspects, the production costs of op- TPS are much less than that of hybrid- TPS. However the quality of hybrid- TPS in terms of tuber yield are significantly better than those of op-seed. (Pallais, 1987a, Golmirzaie et al., 1986, Golmirzaie, 1988, Amin, 1993). Macasco-Khwaja et al, (1983a ,1983 b) found that hybrid progenies had tuber yields of 40 % to 100 % more than op-progenies, thus equaling the yields from seed (tuber) potatoes. The high yields from hybrid seed have been confirmed by trials in the USA and Italy (Concilio, 1987a, 1987b, Love et al 1994).

Successful self pollination and fruit set have been observed to occur in some clones without any human interference (White, 1983). Such seed however will seldom have the characteristics that are desired by the farmers and consumers. By means of the wind or insects, occasional hybridization can take place whilst potatoes are meant to be self pollinating. Research however has shown that the proportion of hybrid seed compared to selfed seed is very low (Arndt, et al, 1985).

Hybridization requires the assistance of mankind with the collection of pollen and the subsequent transferring of pollen to the stigma of the female plants. Potato pollen can be collected by simply mechanical vibration of the flowers (Blomquist et al, 1962). White (1983) suggested that pollen can be collected much easier from flowers that have been cut and dried for about two hours. Commercial use of TPS technology requires techniques for bulk extraction of pollen such as described and developed in India (Thakur et al, 1994). Pollen has been reported to remain functional for up to one year (Blomquist, 1962) but in general it is advisable to use the pollen within hours of collection (White, 1983).

For successful pollination it is essential that male pollen is available and capable to reach the female parts between one and two days after opening of the flower. This can prove to be difficult when the flowering periods of the respective parent plants do not coincide. This can be overcome by either storing the male pollen over a period of time or by planting the parent plants at different dates, thus aiming for a synchronized stage of development later. As the storing of pollen often leads to reduced viability, this method is not commonly used. When self pollination is not desired, it can be prevented by the use of female parents that have (genetically determined) infertile pollen, or by emasculation.

Harvest of berries and seed

Potato berries can be harvested approximately seven to eight weeks after pollination. The size of the berries is between 1 and 1.5 cm, each berry containing between 50 and 500 true potato seeds. The 100 seed weight of TPS varies between 52 and 80 mg. (Upadhya et al, 1985b). The size of the seed varies from 1.3 to 1.8 mm, considerably smaller than that of tomato seeds. The number of berries per plant depends on the number of flowers and successful pollination.

Almekinders et al 1991, found that the weight and number of seeds per berry from primary inflorescence increased with the postponing of harvest date. Pallais et al (1987c) found that additional nitrogen increased the 100 TPS weight. Another method to increase the production of seed is to repeat the process of pollination up to three times per plant within 36 hours of the opening of the flowers (Upadhya et al.

1985a, Pallais et al., 1985).

The potato berries can easily be harvested by hand as the total area in use for TPS-production are relatively small. Kunkel (1979) collected around 2 kg of seed in just two hours with the aid of 4 people. After harvest TPS is extracted from the berries, usually with the aid of some small machine, the size of which depends on the amount of berries that have to be crushed (George, 1985). Once the seeds are obtained, they are usually cleaned, disinfected, dried packaged and stored.

Early estimates for the production potential of TPS came to 150 kg/ha, whilst measurements in the field in Chile came to 200 kg/ha (Umearus,1987). The variation in yields can largely be attributed to the genetic material used and the agronomic skill of the grower.

Seed storage

TPS can be stored successfully over a long period of time, without losing its potential to germinate and produce full grown potato plants. Simmonds (1963) concluded that the viability of seeds starts to decline after six years, under normal storage conditions. However by storing the seed under dry circumstances (over a medium of silica-gel), or at a cool temperature (5 °C), their viability can be maintained for at least eight years and possibly up to 20 years (Simmonds, 1968). Sadik et al (1982) used rice as a medium to dry true potato seed after harvesting.

Howard (1969, 1975, 1980) reported a mean germination rate of 79.6 percent for potato seeds that had been stored for 15 years in sealed glass tubes at a temperature of 5°C. This germination rate dropped to 71.6 percent after 20 years of storage under the same conditions. Howard even suggested that successful germination could take place after 40 years of storage. Similar results of good germination after 15 and 20 years have been reported by others, (Haig 1952, Bohnenblust, 1970, Barker et al, 1980).

Disease Transmission

One of the major advantages of TPS over seed potatoes is the very limited transmission of diseases. From the more than 2000 known potato viruses, only a handful can be transmitted through true seed, whilst the transmission of nematodes is completely eliminated.

The easy transmission of Potato Spindle Tuber Virus (PSTV) by true seed became known in the late sixties (Hunter et al, 1969, Fernow et al 1970). Grasmick et al (1986) found that PSTV has a negative effect on the ability of the potato to produce TPS. Later research showed that TPS can also transmit the Andean Potato Latent Virus (APLV), Potato Virus T (PVT), Andean Potato calico strain of Tobacco Ringspot Virus (TRSV-CA) and the oca strain of arracacha virus B (AVB-O) (Jones, 1982). Borkhardt et al (1994) proposed the use of a digoxigin labeled DNA probe to test TPS for the occurrence of PSTV, whilst Jones (1982) described tests for the other known viruses. Transmission of the above viruses can be easily prevented by the use of healthy parental material (Umearus,1987). Fungi that might attach themselves to the surface of true seed can be sterilized without many problems.

Germination and vigor

Ideally the potato seeds would show a high germination rate and produce vigorous seedlings under a variety of environmental conditions. Simmonds (1963) found that the germination of potato seeds is a slow process, requiring two to three weeks. Obviously the germination of potato seeds is less rapid and vigorous than that of seed potatoes tubers, due to the size and content of the respective "seeds".

Research in the mid-1930's showed that germination is much higher between temperatures of 15 °C and 25 °C, with an apparent optimum germination rate of 75 % at around 20 °C (Clarke and Stevenson, 1943). A steep decrease in germination rate was observed at temperatures over 25 °C (Sadik et al., 1983, White et al,1983). White et al, (1983) found evidence for an even better germination rate under a alternating temperature regime as opposed to constant temperature. As TPS shows great potential for use in (warm) developing countries, some efforts have been made to find varieties that germinate well at high temperatures (Pallais et al, 1987a).

Several studies have concluded that the 1000-TPS weight is positively correlated with the germination and vigor of the seedlings (Pallais, 1987a , Engels, 1987, Dayal et al, 1984). The effect of nitrogen supply to the field with parent plants is inconclusive, as the experiments on this by Tuku (1994) contradicted earlier evidence that showed a better germination rate with nitrogen (Pallais et al, 1987c).

Potato seeds are dormant for about six months after harvesting. The germination of young seed frequently appears to be slow and irregular, as opposed to that of old seed (Clarke et al, 1943, Pallais, 1987b). Dormancy can be broken, and germination greatly improved by a number of simple techniques such as the use of gebbeleric acid (ga), which is also frequently used to break the dormancy of seed potato tubers.

The soaking of TPS prior to planting in a suspension of gebbileric acid (GA3) (1000 -1500 ppm) for a period of eight hours was found the be a very good method of breaking seed dormancy and improved germination by up to 99% (Tuku, 1994, Accatino, 1979, Porter et al, 1979). A much cheaper way is to soak the TPS in distilled water, which can still result in a final germination percentage of 71 % (Tuku,1994). These germination rates however all refer to laboratory conditions and can not be easily duplicated under field conditions.

Tuku and others established that the soaking of the seed in a solution of gebbeleric acid prior to planting helped to break dormancy and increase germination. In the absence of this solution, soaking in water gave good results as well. Bamberg et al (1986) also reported improved germination rates with the use of activated charcoal.

3.3 Breeding Aspects

Caligari (1992) described the aim of potato breeding programs as " to supply growers and the potato industry with improved varieties which make their task easier and more profitable". There is however a large difference in the two main options available to reach this goal, breeding programs that aim for clonal propagation and those that aim for TPS propagation. Traditional (clonal) breeding programs only use sexual propagation to create a wide range of new F1-genotypes from two parents. From these F1 crossings the most desired types are selected and *clonally* propagated. The main task for traditional breeding schemes is to identify just one unique and most useful genotype that is better than its parents, any of the other several thousand genotypes in the F1 population. Once a genotype is found that has all the desirable characteristics, clonal multiplication ensures that all the genetic make up is maintained and copied without many problems.

Breeding programs that aim to identify parental lines that are suitable for TPS technology find a number of extra problems on their way. First of all "The majority of potato species are outbreeders" (Hawkes, 1992), which means that new generations of sexually propagated potatoes consist of a wider variety of genotypes than their parents. Most of all, further sexual reproduction will only increase the number of genotypes and create generations which are largely heterozygous. In commercial terms a heterozygous potato crop means variations in tuber shape, flesh color, flower color, and maturity. This non-uniformity has always been seen as the main disadvantage of TPS technology.

TPS breeders do not aim to establish one unique genotype for clonal propagation, but a stable TPS F1-progeny. A progeny is a large collection of individuals, genotypically different from each other but with sufficient phenotypic uniformity in tuber characteristics etc., that originated from sexual propagation (CIP, 1987). Of course the breeders try to make at least the phenotypic difference in a progeny as small as possible.

The ideal situation for TPS breeding would be the creation of varieties that can reproduce sexually without increasing the genetic diversity. In his paper "Breeding for apomixis in potato, pursuing an utopian scheme", Hermsen (1979) explored the two theoretical possibilities; autogamous multiplication and autonomous apomixis. Under autogamous multiplication one would breed potato varieties that produce fertile, self-compatible and homozygous seed, as is common for barley. This solution however is not seen as very practical for the potato "because inbreeding depression interferes and breeding homozygous lines is (still) too laborious" (Hermsen, 1979). Several other breeders, (Golmirzaie et. al, 1987) also described the negative effects of inbreeding on potatoes.

Autogamous apomixis offers an alternative, but unlike other plant families like the Compositae, Graminae and Rosaceae, this is not very common with potatoes. Hermsen only knew of one successful case of apomixis in potatoes, which happened to be non-tuber bearing. Attention for apomixis in potatoes has always been limited, as vegetative propagation offers a perfect substitute for the commercial growing of potatoes. Hermsen outlines a long and possible way to achieve apomixis in potatoes, but concludes that "it does not warrant the detection of autonomous potato clones ". Regarding apomixis in potatoes, Jongendijk (1985) concluded that the limited available knowledge on the subject could not justify an extensive breeding program.

As the ideal situation appears unattainable for at least until the year 2010, TPS breeders will have to work with second best alternatives. Professional TPS breeders work by either crossing parents at the same, or at different levels of ploidity. Breeding at a diploid level is possible due to First Division Restitution (FDR), which results in a higher level of homozygous progenies. Unfortunately the diploids need longer to mature and have few commercially desirable characteristics. Therefore "The use of tertraploid parental material is the most common to produce TPS " (Golmirzaie and Mendoza, 1988). This produces TPS progenies, with inherent genetic diversity. This diversity however can be limited through various breeding schemes and careful selection of the parental lines for TPS production (Golmirzaie and Mendoza, 1985).

Since the International Potato Center decided to make TPS technology one of its main research activities, many publications have emerged about the experience of TPS breeders (Frusciante, 1987, Jackson 1985, 1987, Landeo 1981, Macasco-Kwaja et.al., 1983). TPS Research of a complementary nature to the needs of breeders includes topics such as; variability of F1 progeny, (Jacubic, 1987), and estimates of genetic variance of progenies (Thomson et al,1984).

The breeding of TPS progenies requires breeders to take many more factors into consideration than is needed by colleagues using the traditional approach. First of all many commercially attractive varieties are sterile or blossom only with artificial inducements. This is no problem for the traditional breeder, as he only needs sexual reproduction under laboratory conditions. The TPS breeder will need large numbers of successful sexual reproduction, if possible at low cost. Secondly when crossbreeding, many varieties have differences in their individual date of flowering, which sometimes makes natural fertilization impossible. This problem can be overcome by either planting the male and female plants at different times, to achieve joint maturity, or by collecting and storing the male pollen until the female plants are ready to receive them.

As most TPS breeding is aimed for end use in developing countries (Mendoza, 1987), breeders have to take a wide range of growing and daylight conditions into consideration. The short photo period in many developing countries works adversely for the setting of seed in potatoes. This leads to one of two solutions, either to produce the seed under long daylight conditions and export it afterwards, or to breed progenies that set sufficient numbers of berries under tropical conditions. Furthermore TPS breeders have to take account of characteristics such as seed vigor, germination, plant uniformity and uniformity of tuber shape, color and taste (Golmirzaie et al, 1988).

Breeders and scientists agree that considerable progress has been made in the breeding of TPS progenies, but also that much work remains to be done. The progress so far is the more impressive if one takes into consideration that it has been made in a relative short time and without the strong financial backing enjoyed by clonal breeding programs. Substantial increases in the funding of TPS breeding seem unlikely so long as the demand for TPS remains unclear, and breeders are unable to protect their intellectual property in an adequate way.

3.4 TPS Agronomy

True potato seed can be used for the production of potatoes (both seed and ware) in three different ways; (a) direct seeding, (b) transplanting, and (c) seedbed production (Monares et. al, 1983). The fact that the use of TPS is a relatively new activity in potato production, means that the search for "the ideal method" has not yet resulted in a conclusive recommendation that favors or eliminates any of the three approaches (Monares, 1984). The appropriateness of the one method above the other will depend on the environmental, social and economic conditions of the region where the TPS is being used. The backgrounds, advantages, disadvantages and experiences with each of these methods will be described, as well as some problems that all methods have in common.

Direct seeding

Direct seeding of TPS is definitely the most appealing means of applying TPS technology for those who look for a tangible revolution of potato production. In the early 1980's the International Potato Center launched the slogan "a hand full of true potato seed equals 2000 kg of seed potatoes". Unfortunately the guideline of using 100-150 gr. TPS/ha. as often stated by various sources like Sadik(1983) and Upadhya (1979) does not always apply for direct sowing.

Additional research has shown that direct sowing can require more than 1 kg of TPS per ha (Upadhya et al, 1985b). Gray (1979) even mentioned seed rates of 1.5 to 9 kg/ha for experiments in England. Only with the use of modern hybrid varieties and specialized precision sowing, is it possible to use seed at a rate of 160 to 230 grams per hectare (Merwe, 1997). The yields from direct seeding can be similar to those of clonal control varieties (Accatino et al., 1979b) or even better (Love et al., 1994).

Bedi (1977) was one of the first to study the direct seeding of TPS in an industrialized country. With the use of 2.5 to 3.8 kg of TPS per hectare he obtained satisfactory yields in New Zealand, and even found that direct seeding led to higher overall yields than the transplanting of potato seedlings (Bedi, 1979).

Extensive research on direct seeding TPS has been carried out in the USA (mainly in Washington State), (Martin, 1983a, 1984, 1986, 1987). Despite some high yields of up to 58 t/ha. (Martin, 1982) "most TPS lines yielded 20 to 36 t/ha, which was only 30 to 50 % of the yield from tuber planted plots" (Martin, 1983b). The overall conclusion was that the performance of a potato crop grown from seed potatoes resulted in a higher yield, larger tubers more uniformity of type and a better quality. Martin (1987) therefore concluded that direct sowing of TPS into the field would find its best use in breeding programs, in order to identify and save valuable genotypes.

The interest in the use of direct sowing has increased over recent years with the commercial developments led by ESCA-genetics. This company has successfully converted a direct sowing machine for tomatoes, for the direct seeding of potato seeds.

Transplanting

Rice and a large number of vegetables (e.g. lettuce, cabbage, spinach) are grown by the planting of small seeds into nursery beds and subsequent transplanting into the field. Technically it is quite possible to cultivate the seeds from the potato in a similar way. Many farmers in developing countries already have ample experience with the cultivation of vegetables from small seed and transplanting them into the field. For other vegetables there already exists trade of transplants of other from one farmer to the other (Sadik,1983). Research activities on the transplanting of potato seedlings has been very diverse and has touched upon many different aspects of the agronomy. Conclusive advice on the ideal agronomic practice however has yet to be established.

The seed rates used in many of these experiments have been considerably lower than those used in most of the direct seeding research. Song et al. (1987) used seed rates of 200 to 500 gr./ha. for China., whilst Shakya (1985) used a seed rate of 370 grams per ha.

One of the major problems with transplanting potato seedlings is the occurrence of plant shock (Lauer, 1981). The effect of shock appears to be increased by short days and low temperatures, when they induce tuberisation of the seedlings before planting. In one experiment on the transplanting of potato seedlings it was found that 100 % of the transplants had started tuberisation before transplanting, thus limiting the success rate (Schwenkel, 1987). Additional doses of phosphorus appear to reduce the transplanting shock (Sattelmacher, 1987).

Risse et al (1984) found that higher temperatures during storage of the transplants for up to six days, had a negative effect on their final performance. Research by CIP (Malagamba, 1987a), found that recovery of the seedlings from plant shock was closely related to early root regeneration of the seedlings. As root regeneration is genetically determined, this could serve as an indicator for potential successful progenies.

In India survival rates of 70-75 % of transplanted seedlings have been obtained, with an overall success rate for TPS of about 50 %. (Upadhya, 1979). The success rate at transplanting can be increased up to 90 % with the use of soil blocks. Wiersema (1982) found that on average 86 % of the yield from transplants is marketable, whilst total yields are lower or equal to those of conventional seed potatoes. Only in Korea did he find that the yield was higher than that of conventional seed, but the marketable yield was still less.

Malagamba (1984) suggested to transplant the seedlings when they have developed their fifth leaf, which is usually at a height of 8 to 10 cm. In subsequent research he found that a substrate mixture with a high percentage of organic material (50 % sand and 50 % peatmoss, plant compost or manure) were very suitable for the establishment of seedlings from TPS (Malagamba, 1983). Research in Egypt (Engles et al, 1994), found that field establishment and yield were much lower from seedlings that were transplanted in the spring season compared to the autumn season. This was thought to be the result of premature tuberisation of the spring-seedlings in the nursery, thus weakening the plant's strength.

Jaworski et al (1986b), obtained satisfactory results by transplanting seedlings after a much longer period (57 days) and suggested that large-scale, mechanized field production potato transplants, similar to that of tomato transplants, would be possible in industrialized countries. During field experiments in Georgia, USA his team harvested marketable transplants (height > 9 cm, diameter > 2 mm) at rates of 650,000 to 1,315,000 plants per hectare, which corresponded to 86 % of the total number of plants that emerged. He found no effect of the seed rate on the percentage of marketable transplants (Jaworski et al, 1986a). Transplanting has the problem that one can not always transplant when it is biologically needed, due to bad weather. Transplanting after the optimum date leads to lower success rates and yields (Shakya,1985). Heavy selection amongst the transplants (removing 80 % instead of 20 % of the seedlings) had little impact upon the yield (Shakya,1985).

Accatino (1979a) used plastic trays to raise potato seedlings until they were 6-12 cm high and had a density (after thinning) of one seedling per cm2. He found no marketable difference between transplanting of seedlings with bare roots and seedlings with soil covered roots. The yields he obtained however were low, which might well be ascribed to the fact that he used an open pollinated progeny. The main advantage he found was the high cost of the (imported) trays and Jiffy mixture, which brought the accumulated costs of seeding (not including the purchase of TPS) and transplanting to more than cultivation of to some \$ 3,000 per ha. Thus making this method of TPS use unlikely to succeed in developing countries. Other (commercial) trials on the effect of altitude on the transplanting of potato seedlings have been carried out in Costa Rica (2160 m and 1400 m), but unfortunately no results were published (Ball, 1994).

<u>Seedbed production</u>

The use of TPS to produce seedling tubers for the following season, combines many of the advantages of TPS with the relative more simple usage of seed tubers. One of the problems with direct sowing and the transplanting of TPS, is the considerable horticultural skill that is demanded from growers. The TPS- tubers however, can be produced by specialized horticulturists for use by traditional farmers without much extra effort. The husbandry for TPS-tubers is identical to that of tubers from a traditional back ground.

The immediate disadvantage of TPS used in this way, is the return of many problems such as seed storage, transport costs and susceptibility to pests, that the use of TPS was aiming to overcome. Still the use of TPS-tubers can bring substantial progress, if the existing situation used heavily degenerated seed with low yields. Wiersema (1984) reported that in 1979 TPS-tubers were used to plant an area of 21,660 ha, outperforming standard cultivars by 29% to 155 % in terms of yield.

The International Potato Center, and especially Wiersema (1983, 1984, 1985,1986a, 1986b, 1987a, 1987b), has spent considerable effort on the improvement of production methods for TPS-tubers. Initially this research focused on ways to establish an appropriate type of nursery with a suitable medium and the need for fertilizers. Subsequently the focus of the research moved to the comparison of the field performance of TPS-tubers with that of traditional tubers.

Wiersema (1984) advised nursery beds 1 m wide, with a depth of 25 cm. and pathways of 65 cm. This effectively means that per ha. in use as nursery, only 6,000 sqm (60%) will produce TPS-tubers. In considering large-scale production of TPS-tubers, it is important to adjust the high nursery yields in kg/sqm for the yields per ha. of nursery. Nurseries following this lay out will also need around 1,500 cubic meter of substrate or growing medium per ha. In warm climates it will be necessary to lower the soil temperature by applying shade on the beds.

The requirements for growing substrates are similar to those for raising TPS-transplants. Traditional hilling of the potato plants in the nursery is not feasible although desired to prevent tubers from coming to the surface. Wiersema used to sow the seed in beds of 20 cm depths, followed by an addition 5 cm substrate layer once the plants had established themselves. Plant densities of 150 to 200 plants per sqm. provided a good yield in terms of seed weight, size and number.

The occurrence and transmission of soil-born diseases through TPS-tubers can be greatly reduced by sterilizing the nursery substrates prior to sowing. With this practice the TPS-tubers will maintain a better health status than traditional tubers raised in non-sterilized soils. The yields from the nurseries vary from around 2 to 10 kg/m2 (Bedewy et al. 1991). Adjusted for the space used as pathway in the nursery (40%) and the marketable seed tuber yield (75%), this leads to seed tuber yields of 9 to 45 t/ha. A realistic target of 6 kg/m2, will therefore result in a useable seed tuber yield of 27 t/ha. Malagamba et al (1987b) did not find a significant difference in yield between op and hybrid progenies, when the tubers harvested from seedbed were used as seed for the production of ware potatoes.

El Bedewy et al (1991a, 1991b) estimated and subsequently measured the cost price of seed tubers from TPS-nursery beds in Egypt to be at around $ 600 per tonne. For Egyptian potato production, this method can lead to a reduction in the price of planting material of more than 50%. Interestingly peat moss and plastic accounted for more than half of the production costs, whilst the use of TPS only made up 2.5% of the costs.

Other agronomic aspects

The planting of TPS is troublesome because of the very small size of the seeds (<0.6 mg/seed), which is only one fifth of the size of a tomato seed. Sowing by hand will therefore give an uneven distribution of seeds and plant stand. The international research community has made little study of the ways to mechanize the sowing of TPS and transplanting of potato seeds (Ghate et al, 1983). Pathak et al (1986) suggested that conventional garden planters might be converted for the use of TPS seedings in the tropics. However preliminary research showed that unless the seed was pelleted, even distribution could not be achieved. Gray (1979) proposed germinating the potato seeds under ideal conditions, suspending them in a protective gel. Following this, the gel, rather than the dry seeds, would be distributed over the field with a fluid drilling machine. Martin (1983) used a mechanical precision planting machine (International Harvester model 180) that plants 3-5 seeds in each hole drilled, for his experiments on direct sowing. In his case the coating of TPS gave no clear advantages over raw seed, and therefore only caused a rise in costs (Martin, 1988). Unfortunately the call by Gray for substantive research on the engineering aspects of TPS remained virtually unanswered.

Emergence of directly sown TPS is generally low, with reported rates of only 6% (Upadhya 1979). Low emergence itself does not have to be a problem for successful potato production, as other vegetable seeds like celery rarely have an emergence rate of more than 20% (Gray, 1979). For potatoes an emergence as low as 10% is still sufficient to produce a full crop (Martin, 1988). A low emergence rate does however increase the necessary seed rate/ha and therefore the production costs. The findings by Clarke (1943) suggest that planting at a depth of 1/8 inch (0.3 cm) give the best germination results, in comparison to plantings at greater depth. The emergence of TPS in nursery beds was also found to be increased by light irrigation just before sowing, and by covering the newly sown beds with straw or wet gunny bags (Uphadhya, et al, 1990). A factor that adversely influences the emergence is the crusting and cracking of the soil, thus causing a loss of seed (Accatino, 1979).

3.5 A brief history of TPS technology

The first use of TPS technology probably dates back to the Inca's who were among the first to cultivate the potato (Malagamba et. al, 1988). In the few centuries TPS has also been used by farmers in Europe, North America and Asia to produce healthy planting material when the existing stock of seed tubers had degenerated (Burton, 1989). Until the second World War botanical potato seeds were still being sold on a commercial scale in the UK (Geddes, 1988). By 1949 the first breeding program for TPS-varieties was started in India, but it did not prove to be successful. (Gaur, 1990). In 1971 the research and development of TPS technology were given a major impetus when the International Potato Center declared it as one of its major research areas. Since then TPS technology has been studied or applied in a great number of countries (see Table 3.1).

Table 3.1 Overview of global research on TPS technology.

Country	Reference
South America	
Argentina	Bianchini, et al. 1985
Brazil	Fedalto et al.1987
Caribbean	Fernandez et al.1984
Chile	INIA
Costa Rica	Leue,1985
Nicaragua	CIP
Paraguay	CIP
Peru	Achata, 1987
North America	
USA	Martin 1986
Mexico	Fernandez et al. 1984
Africa	
Burundi	Hardy et. al. 1995
Egypt	Bedewy et al. 1991
Ethiopia	Tuku 1994
Morocco	Hilali 1985
South Africa	Merwe, 1997
Rwanda	Haugerud et al. 1986
Sudan	Amin, 1993
Europe	
Austria	Herber 1990
Finland	Ahonen et al.1987.
Germany	Sattelmacher 1987

Country	Reference
Italy	Frusciante 1987
Netherlands	Schepers 1984
Spain	Kidd 1994
Sweden	Ahmed, 1987
Ukraine	Kidd 1994
UK	Clulow 1994
Asia	
Bangladesh	Ahsan, et al 1987
Bhutan	Karmacharya,1983
China	Song et al 1987
India	Gaur 1990
Indonesia	Almekinders, 1996
Pakistan	Devaux & Farooq et al 1987
Philippines	Zaag,. vander 1987
Korea	Zaag,. vander 1987
Nepal	Gaur 1990
Syria	Hardy et. al, 1995
Sri Lanka	Jackson 1987, Bryan 1986
Taiwan	Umearus 1987
Thailand	Thjongjiem et al 1986
Turkey	Scott,1994
Vietnam	Zaag, vander 1987
Australasia	
New Zealand	Bedi, et al 1979
Samoa	Jackson,1987

In these studies remarkably little attention has been given (so far) to the economic side of the technology. Table 3.2 presents on overview of the TPS prices that have been quoted at various places in the literature

Table 3.2 Various prices quoted for TPS.

Cost price of 1 kg TPS (US $)	Source:
1000 - 1,500	Hybrid TPS from INIA Osorno Chile
340	Hybrid seed, according to Monares & Achata, 1988 (without a return on investment.)
10 % of seed potatoes	Unspecified, Chilver 1994
10	Open pollinated in China, Song et. al 1987
42	Open pollinated, in Vietnam, Vander Zaag, 1987 (deduced from the barter trade in; 1 kg rice for 1 kg of rice estimated at $0.30/kg.)
30	Hybrid seed, 1990 India Gaur, 1990.
1600	Hybrid seed, TPS Products company, Renia 1995.

By far the greatest part of world wide research on TPS has been aimed at developing world countries. That doesn't mean that there has been no interest for the application in European countries. In the early 1980s a Dutch research group was achieving yields of more than 55 t/ha from TPS transplants (Scheper, 1984). There has also been interest from Austria (Herber,1990) and Germany (1987). In the UK Maine (1996) has studied the prospects of using colorful TPS varieties to supply niche markets. Most of the European TPS-research has been carried out in Italy. According to Martinetti (1987), TPS could solve the seed production problem, save money, and alleviate the problems surrounding crop establishment, storage and transport. In the south of Italy breeding schemes have been set up to explore the possibility of TPS use (Frusciante, Peloquin, Leone, 1987).

Furthermore trials were made with transplanted TPS-seed, originating from CIP progenies. This seed reached an average yield under Italian conditions of 24.88 t/ha (Martinetti, 1987). The yield however showed a large percentage of tubers with a diameter < 30 mm, which reduced the marketable yield. However is was suggested that the percentage of large tubers could be increased by more suitable agronomic practices. It may be expected that European interest in TPS technology will follow the developments and increased interest that has taken place in the USA (Section 3.6)

3.6 Recent developments in the USA

In comparison with other industrialized countries, the USA has always taken the most positive stand towards the use of TPS technology. As early as 1882 the owners of allotment gardens were taught how to save, sow and raise potato seeds for human consumption (Anon, 1882). In 1976 Pan-American, a subsidiary of the Geo J. Ball seed company, initiated a large research and development project to commercialize the potential of TPS (Leue, 1985). The project has however been terminated in the mid 1980s due to limited sales, high variability in yields and import restrictions of TPS into the USA and EEC. At the end of the 1980s America's largest seed potato company (Pioneer) and ESCA-genetics, a biotech company from California, set up a joint venture research project in order to develop the commercial potential of TPS. The project resulted in the establishment of the TPS Products Company, which is currently the only company that markets TPS technology for industrialized countries (Kidd, 1994). In 1996 ownership of the TPS Products company was transferred to Potato Products International.

Special attention to the approach of the TPS Products company is justified, as it is the first and only company that successfully markets the use of TPS for high quality markets in industrialized countries. It is expected that other biotechnology and vegetable seed companies will enter the market should the commercial viability be been proven. The R&D program of the TPS Products Company started in 1980, with the collection of wild (flowering) potato plants throughout the Andes region. This resulted in a genebank of more than 400,000 genotypes, which formed the basis of an extensive breeding program. The development costs between 1980 and 1995 were estimated to be in excess of $ 25 million (Renia, 1995).

The breeding program used many modern biotechnological techniques such as genetic fingerprinting of parental lines of potatoes. This technique enabled the selection and breeding of potato varieties that flower profusely without artificial assistance. The breeding resulted in a large number of parent plants that are capable of producing several stable hybrid potato varieties. Nine of these varieties have been registered in various American states. A more detailed description of five of these varieties and their characteristics is presented in Appendix A.2.

All these above mentioned TPS varieties can be produced successfully in the USA, but the high labor costs make the final product very expensive, possibly more than \$15,000/ kg (Sepulveda, 1995). To reduce production costs, in vitro cuttings of the parent plants are flown to a subsidiary company in Osorno, Chile, where they are raised in disease-free greenhouses. There the parent plants flower and get pollinated by hand. The long day length in the south of Chile proves to be very beneficial for the production of TPS and true seed yields in excess of 100 kg/ha are possible. The TPS production site in Chile is isolated from potato disease by the Pacific Ocean, the Andes Mountains, the Arctic cold and the Tolten river. The production costs of TPS in Chile are as little as \$ 1,750 /kg. After harvesting, drying and cleansing of the seed, the TPS is packaged and sent by airmail to the end users in the USA and other countries.

The agronomic practice of TPS use in the USA is based upon direct sowing of the seed by means of a converted tomato sowing machine. Typical seed rates for potato lie between 250,000 and 350,000 seeds (160-230 g) per ha. From these seeds, approximately 90% will germinate and of these another 80 % will demonstrate the desired vigor. Thus the total emergence of the sowing tends to be around 75 % (Sepulveda, 1995). After approximately 120 days the plants form 4 to 12 mini-tubers per plant, with an average weight of 25-30 gram. The number of tubers per plant depends largely on the horticultural skill of the grower. Depending on the desired product, one can either harvest the mini-tubers after 120 days, or harvest ware potatoes (50-60 gr.) after a longer growing period. For the production of ware potatoes straight from TPS, a lower seed rate would be sufficient.

Potatoes have been grown from TPS in some American states such as, Oregon, Washington, and California. Besides a skillful grower, the potato seeds need a soil temperature of 10 °C and a frost free growth period of 120 days. Trials by the University of Idaho concluded that the nine registered TPS varieties compete well with clonal varieties for total yield. There were only few problems with appearance, whilst size distribution from TPS lines was considered as normal. The processing qualities of all TPS varieties proved to be as good or better than the clonal control groups (Love, 1994, Love 1996). The dry matter and reducing sugars content in the tubers of these TPS varieties is stable. As a result of the successful breeding program, the tubers from the TPS-varieties are uniform in skin color as well as flesh color, their shape is regular and a high proportion of the tubers are between 40 and 80 mm (Spudman,1992).

Table 3.3 Yields of TPS varieties in the USA.

Variety	Yield (t/ha)	<40 mm %	40-80 mm %	> 80 mm %	Tuber shape*
ES-1	48.9	6	25	66	2.8
ES-2	46.7	2	26	63	3.9
ES-3	48.8	5	26	61	3.3
ES-4	40.2	10	24	61	1.8
ES-5	51.2	6	29	61	3.5
ES-6	50.3	10	27	58	2.3
ES-7	59.6	9	38	50	3.4
ES-8	54.7	10	42	45	4.5
ES-9	41.0	5	34	54	3.5
Alpha	45.7	3	23	53	2.9
Brador	43.0	3	15	71	1.9
Katathdin	56.3	2	17	79	4.0
Superior	37.6	3	41	54	4.3

*Tuber shape 1= long, 5= round

Source: Love, 1994.

Widespread adoption of TPS technology in the USA has been hindered by the fact that the production of potatoes from seed requires a great amount of horticultural skill. Thus it is unlikely to be a straight forward substitute for the average ware producing farmer. TPS is generally bought by specialized potato producers who grow the seed into mini-tubers which they than sell off to ware growers.

The use of TPS from Chile brings the costs of potato seed down to $ 585 per hectare. Mini-tubers from TPS are sold with the slogan "Nuclear seed for the price of 4th generation seed". TPS technology makes it uneconomic and unnecessary to use low quality, uncertified seed as it makes sufficient low-priced certified seed available. The very good health status of TPS-mini-tubers, makes it often possible to produce certified seed outside the traditional seed producing regions. This again helps to reduce the transport costs from the producer of seed tubers to the ware growers.

The import of TPS was not allowed by the USA authorities until March 1995. This seriously reduced the economic advantages of TPS. Extensive trialling and testing throughout the USA however resulted in an change of regulations, allowing the import of TPS from Chile. The reason behind the change was to "give potato producers in the United States another means of producing disease-free tubers." (USDA, 1995).

3.6.1 The Potential use of TPS in the EU

The developments in the USA suggest that TPS technology would also be a technically feasible alternative of seed tuber production. The most likely scenario would that whereby

i TPS is imported from a low wage country, at world market prices (2460 ECU/kg).

ii TPS is direct seeded at a rate of approximately 200 g per hectare, and expected to yield 18 tonnes of seed tubers per hectare.

iii The seed tubers derived from TPS will be used for the production of ware, early, starch or seed potatoes.

iv TPS technology will allow the production of certified seed tubers outside the traditional seed tuber producing areas.

4. AGRONOMIC ASSESSMENT OF USA-BRED TPS VARIETIES IN THE EU[1]

4.1 Introduction

In February 1995 the law that prohibited the import of TPS into the USA, was changed to the effect that TPS material that had been produced in the Tenth Region of Chile could be imported in commercial quantities for end use in the USA (USDA, 1995). This legislative system, combined with ESCA-genetics' progress in the breeding of varieties and the production of seed (Kidd, 1994) meant that "TPS is a commercial reality in the USA" (Renia,1995).

It was expected that several hundred hectares of potatoes would be grown from TPS by 1996, with rapid expansion in the subsequent years. The uptake was halted by the fact that ESCA-genetics corporation got into financial difficulty (because of a failed date palm project in the Middle East) and finally filed for bankruptcy in January 1996 (Renia, 1996). In late 1996 the TPS-Projects company was bought out of ESCA-genetics by a private investment fund, and renamed into Potato Projects International. According to M.Kline, president of Potato Products International, the company aims to start up the supply to farmers in the USA and elsewhere with high quality TPS and TPS-varieties.

The positive developments in the USA led to the obvious question as to whether the current and future USA-bred varieties would also find a place in the EU-potato industry. There are significant differences between the potato industries of the USA and EU (see chapter 2, Siecza et al. 1993, NPC 1996). At the same moment however both industries cater for quality conscious consumers in highly sophisticated and industrialized markets. Several important potato varieties that were bred in North America have found their way into the EU's potato industry e.g. Atlantic, Kennebec,

[1] The trials described in this chapter would not have been possible without the great support of the Scottish Agricultural Science Agency. Due to quarantine legislation, the seeding and growing of potato plants from the botanical seeds had to be carried out by SASA-staff members.

Russet Burbank, Shepody (SSPDC,1996). The two industries already have numerous linkages in area's such as scientific research, processing, machinery and commerce. Thus when a new technology like TPS makes inroads into the USA, it only seems a matter of time before similar developments can be expected in the EU.

This chapter outlines the first study in the EU that has been set up to assess the potential role of nine USA-bred TPS varieties in the EU. The aim of the project is to assess the field and culinary performance of nine TPS varieties (see appendix A.2 for a description), under EU growing conditions. Since the total assessment cycle spans a period of three years, only the first year's results can be presented in this thesis.

4.2 Methodological Outline

The first requirement for a study on the performance of USA-bred TPS varieties, is to obtain a sufficient amount of botanical potato seeds to carry out the trials. This can be achieved by either (1) Importing botanical potato seeds from a country where they are being produced on a commercial scale, or (2) Producing botanical potato seeds inside the European Union. The option of importing botanical seeds from elsewhere is certainly the fastest, and the least labor intensive.

The import of botanical potato seeds from any country outside the European Union is prohibited by the EU Plant Health Directive 77/993/EEC although botanical potato seeds may be imported under license based on the decisions 80/862/EEC (amended 91/22/EEC). The import license states that the botanical potato seeds will have to be placed in one of the EU-approved quarantine units directly after their arrival in the EU. The subsequent quarantine testing involves the individual germination of all the botanical seeds, and a range of health tests on the plants and tubers that grow from these seeds. Only when the EU-plant health authorities are fully satisfied that the botanical seeds do not carry any known harmful organism, will they allow the release of any tubers or plants.

Abiding by the EU-legislation on the import of botanical seeds, makes it impossible to obtain even a single botanical seed for the assessment of direct seeding or transplanting under normal field conditions. Nevertheless it is possible to undertake some form of study on the field performance of these varieties. The botanical seeds can be studied whilst growing under quarantine, and (after release from quarantine) the resulting tubers can be used for trials with first generation seedling tubers.

Another disadvantage of importing botanical seeds into the EU is the considerable costs that accompany the quarantine process. An initial plan to import and germinate a total of 2700 seeds (300 seeds of each variety with a total seed value of ca. £ 3) was rapidly curtailed when quarantine costs of £ 14,850 emerged. The lowest rate of quarantine costs is that for common and scientific use, which still comes down to £ 5.50 per botanical seed. For commercial purposes the actual quarantine cost may be charged, which are up to three times higher (Jeffries, 1996). It will be clear that these quarantine costs place a serious financial constraint on any study of TPS-material from outside the EU.

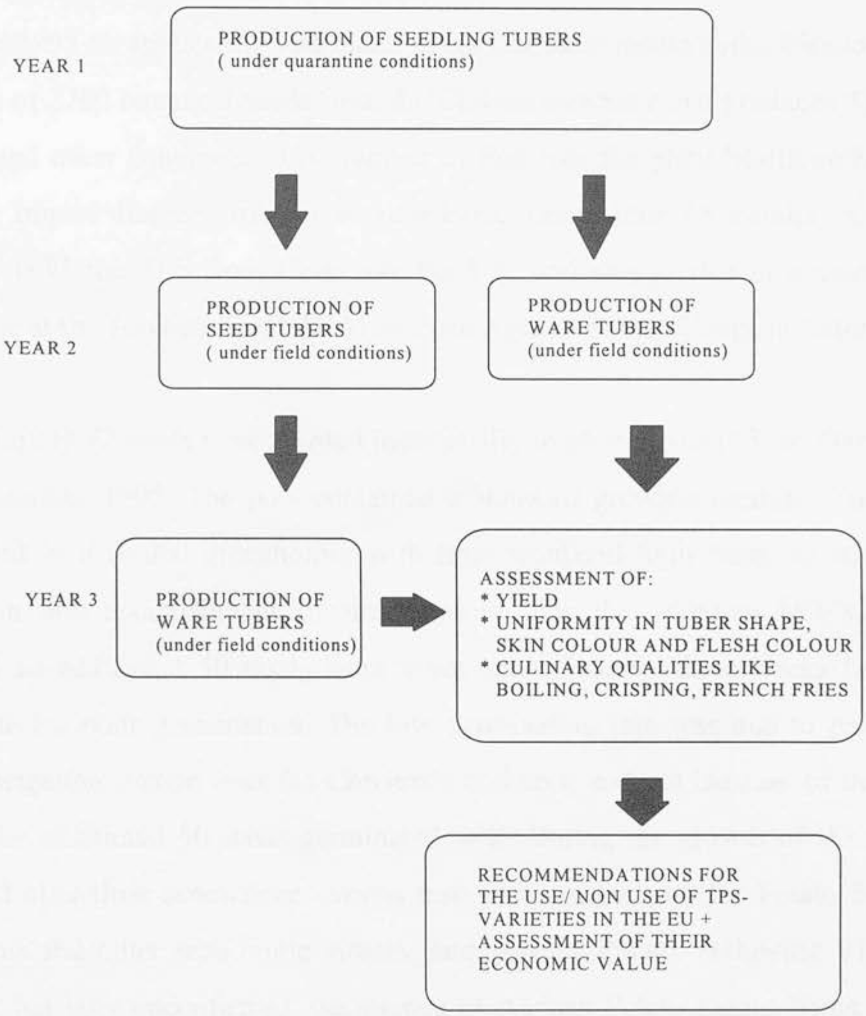
An alternative to the import of TPS is the production of some botanical potato seed inside the EU. Only a few parental plants are needed to produce a reasonable quantity for testing. Every potato berry contains several hundred seeds, and individual plants are capable of producing several grams of TPS (i.e. several thousand seeds). Under commercial conditions it may take as little as four female plants to produce the seed for one hectare (Santos Rojas,1996). For the TPS varieties from the USA the option of small scale production in the EU is limited because of technical and commercial constraints.

The technical constraints stem from the fact that the parental material for the American TPS varieties is not available inside the EU. Therefore these parents would have to be imported as in-vitro material, and placed under quarantine at one of the approved EU quarantine stations. After release from quarantine the parental material would have to be grown into full potato plants, and be hand pollinated by a skilled individual. Thereafter the seed will have to be collected from the potato berries. Under optimal conditions TPS can be recovered some 12 months after the import of the parental material. Because of the seasonally of potato production, these seeds can not be planted until the following season, which effectively brings the time between initial import of the parents and planting of the TPS to 18 months. In Italy several trials have been done with TPS-varieties from the International Potato Center. For all these trials, the scientist in charge has always produced his own botanical seed, (Fruscianti, 1996)

The commercial constraint to the production within the EU stems from the fact that the parental lines are proprietary to the breeder, and as yet not registered for plant variety rights in the EU. Once the parental lines are imported into the EU, the breeder would have no way of maintaining his intellectual property rights. A European competitor who would manage to obtain only one stem cutting from each parental line, will find no legal obstacles in his way to start the mass production of these TPS varieties. This commercial restriction has been the decisive factor for the owner of the TPS varieties not to allow the production of TPS in the EU, without the purchase of an EU wide production license. Therefore only the option of importing a small quantity of TPS remained in order to study the performance under European conditions.

The following outline is proposed as a basic method for the testing of TPS varieties from outside the EU

Figure 4.1 Scheme for the assessment of USA-bred TPS varieties in the EU.



The scientific ideal for the assessment of the American TPS varieties would be to conduct the above scheme of testing in all countries of the EU, and preferably in different production areas. Limitations of funding meant that initially it will only be possible to test the field performance of these varieties in one country, and in three locations. The time limits on this study also meant that it was not feasible to conduct the full (three-year) range of assessments within the prescribed study period. Only the first year of trial activities could be carried out. However co-operation has been achieved with several organizations in the UK, who aim to complete the three year assessment by the end of 1998, and publish their findings (see 4.5).

4.3 Materials and Methods

In October 1995 an application was made to the UK plant health authorities to allow the import of 2700 botanical seeds from the Chilean company that produces TPS for the USA and other countries. In November of that year the plant health authorities issued an import license, subject to quarantine restrictions (Appendix A.3). In December 1995 the TPS from Chile into the UK, and was seeded in a quarantine green house at the Scottish Agricultural Science Agency at East Craigs in Edinburgh.

For each variety 72 seeds were planted individually in plastic pots (15 cm diameter), on 27 December 1995. The pots contained a standard growing mixture. The pots were placed in a heated greenhouse, with time regulated light bulbs to stimulate germination and establishment of the potatoes. For the varieties 88.EX.2 and 88.WR.35 an additional 50 seeds were sown approximately three weeks later, to compensate for poor germination. The low germination rate was due to problems with the irrigation system over the Christmas holidays, and not because of the seed quality. The additional 50 seeds germinated well. During the growth of the potato plants, and after their senescence various tests were carried out for Potato Spindle Tuber Virus and other seed borne viruses, and also the Potato Yellowing Virus. A suspected, but later unconfirmed, occurrence of Andean Potato Latent Virus meant that extra tests had to be carried out. The time needed for these extra tests caused a delay in the release of the tubers, whereby the opportunity to plant them out in 1996 was lost. Harvesting took place on 5 August and 19 September 1996.

The number of tubers in each pot were counted, weighed and graded for size. The full results of these findings are presented in Appendix A.4 After harvesting the tubers were placed in the cold store of the UK quarantine section, awaiting the outcome of further tests and the release from quarantine.

4.4 Results of first growing season

Establishment

All varieties produced a number of plants, but some less than others. The failure of some seeds to establish successfully might be due to problems with the growing medium. The foliar development per variety sometimes showed considerable variation.

Table 4.1 Establishment of TPS varieties.

TPS-variety	# seeds planted	# plants grown	establishmen t %	# plants harvested *
88.EX.2	122	80	66	62
88.WR.32	72	64	88	52
88.WR.33	72	69	96	61
88.WR.35	122	99	81	85
88.WR.49	72	63	88	25
88.WO.13	72	56	78	32
89.FWW.3	72	67	93	55
89.FWW.102	72	59	82	44
89.FWW.105	72	61		53
Total	748	618	83	469

* The number of plants harvested is less than the number of plants that actually emerged. This is caused by the fact that several plants have been removed for the purpose of testing and/or roughing.

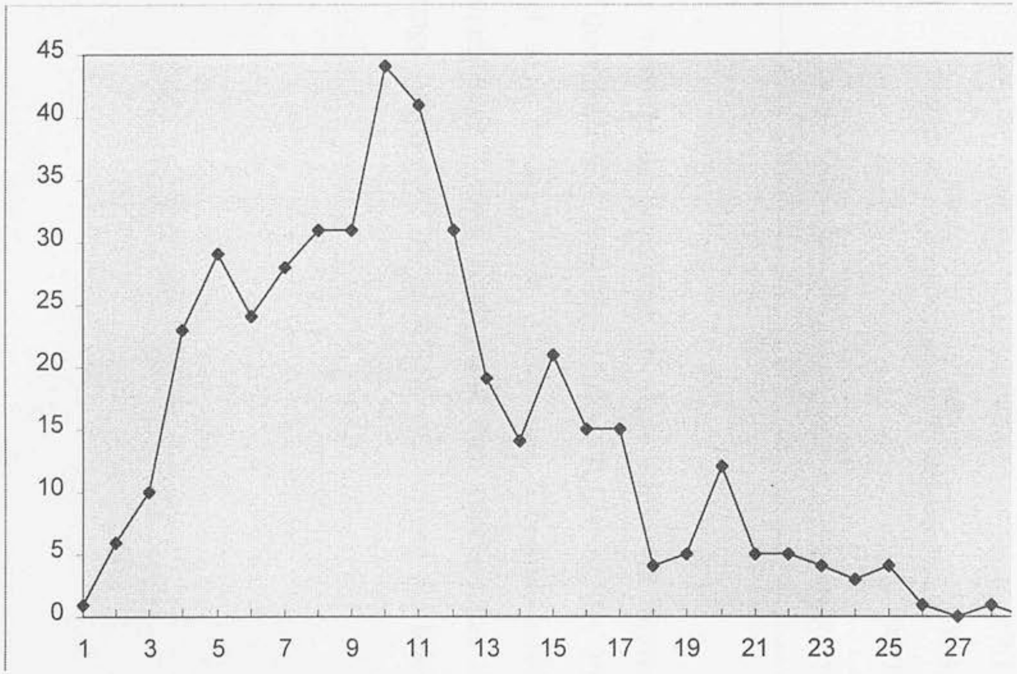
Tuber counts

The tubers that had been formed in each pot were counted, and the results are summarized in Table 4.2.

Table 4.2 Tuber counts.

TPS-variety	min. per plant	max. per plant	mean per plant	total per variety
88.EX.2	4	28	11.7	725
88.WR.32	2	25	9.7	503
88.WR.33	4	25	10.4	635
88.WR.35	2	17	7.2	610
88.WR.49	1	21	11.1	278
88.WO.13	2	34	15.6	506
89.FWW.3	3	20	10.9	599
89.FWW.102	4	22	10.5	460
89.FWW.105	3	53	15.1	798
average			11.4	

Figure 4.2 Distribution of tuber numbers per plant.



Number of tubers per plant.

Yields

The average yield of the TPS varieties was between 71.9 and 108.1 gram per plant.

Table 4.3 Yields per plant and variety (g).

TPS-variety	min. per plant	max. per plant	mean per plant	total per variety
88.EX.2	8.4	203.0	87.6	5433.4
88.WR.32	3.2	137.1	84.4	4386.3
88.WR.33	23.4	128.5	89.7	5474.2
88.WR.35	14.9	151.3	92.1	7825.7
88.WR.49	0.8	164.1	85.7	2142.0
88.WO.13	6.3	167.8	71.9	2300.9
89.FWW.3	18.3	163.0	89.1	4901.7
89.FWW.102	59.4	145.5	108.1	4755.7
89.FWW.105	9.3	182.6	96.7	5125.8
Average all 9			89.7	

Size grading

All the tubers were grade according to size. Table 4.5 shows the percentage distribution of the tubers over these size classes. Tubers of 5 to 20 mm are suitable for commercial seed production in glasshouses (Coombs, 1990). Therefore on average the "marketable " yield of all these nine varieties lies above 82 %. The highest percentage is achieved by 88.WR.35 (92 %) and the lowest by 88.WO.13 with 74 %

Table 4.4 Grading of tubers by size (mm) and variety

TPS-variety	< 10 mm %	10-20 %	20-30 %	30-40 %	40-50 %	> 50 %
88.EX.2	23	21	24	19	8	5
88.WR.32	21	26	23	19	9	2
88.WR.33	14	37	26	15	7	1
88.WR.35	9	28	25	24	12	2
88.WR.49	15	35	27	19	5	0
88.WO.13	24	27	26	16	6	1
89.FWW.3	19	37	27	13	4	1
89.FWW.102	15	29	27	20	7	3
89.FWW.105	18	30	25	18	7	2
Average all 9	18	30	25	18	7	2

Table 4.5 Average number of tubers per plant, by size (mm) and variety

TPS-variety	< 10 mm	10-20	20-30	30-40	40-50	> 50
88.EX.2	2.7	2.5	2.8	2.2	0.9	0.6
88.WR.32	2.1	2.5	2.2	1.8	0.8	0.2
88.WR.33	1.5	3.8	2.7	1.6	0.8	0.1
88.WR.35	0.6	2	1.8	1.8	0.8	0.1
88.WR.49	1.7	3.9	3	2.1	0.5	0.0
88.WO.13	3.8	4.3	4.1	2.5	0.9	0.1
89.FWW.3	2.1	4	3	1.4	0.4	0.1
89.FWW.102	1.5	3	2.8	2.1	0.7	0.3
89.FWW.105	3.5	4	3.4	2.7	1.3	0.2
Average all 9	2.2	3.3	2.9	2	0.8	0.2

4.5 Framework for subsequent seasons

In March 1997 the tubers described in the previous paragraph were released from quarantine, and issued with plant passports (see Appendix A.5). The tubers were separated into three batches, for planting in the 1997 growing season.

The first batch consisted of the 120 largest tubers of each of the nine varieties. These tubers will be used for a PMB-funded variety assessment, which will be carried out by the Scottish Agricultural College (Johnson,1996). In April 1997 these tubers were planted in three replicated plots of 40 tubers per variety, on a field of the Scottish Agricultural College's experimental farm on the Bush Estate near Edinburgh. These tubers will be grown for ware production, and assessed for yield, uniformity of tuber shape, flesh color and skin color. The ware tubers that will be harvested from this will subsequently be tested for their processing (especially crisping) qualities at a laboratory of United Biscuit's (Vessy,1996). The remainder of the ware harvest will be used for small-scale cooking and eating tests.

The second batch consists of the 200 second largest tubers of eight of nine varieties, and the remaining tubers of 88.WR.49. These will be used by Nickerson, a commercial seed potato company, for a similar type of assessment as the one funded by the PMB. The tubers have been planted in Lincolnshire, England in April 1997. These tubers will also be grown for ware potato production (Coombs, 1997)

The third batch consists of the remaining (smallest) tubers of each variety. In 1997 these smaller tubers will be used by Nickerson for the production of seed potatoes that will then be planted out in 1998. The ware crop grown from these tubers will then be assessed in a similar way as the first two batches.

Depending upon the results of 1997 and 1998, and the interest from the industry in the UK and elsewhere in the EU, more experiments with these USA-bred varieties may be expected.

4.6 Preliminary conclusions

The assessment of US-bred varieties in the EU is more difficult than that of traditional potato varieties due to the problems in obtaining a sizable quantity of botanical seed. A total of 2700 botanical seeds were imported into the EU, and a small proportion of these germinated and produced seedling tubers. Since this assessment procedure will not be completed until 1998, and the first results from field trails will not be available until the autumn of 1997, only a few preliminary conclusions can be drawn;

- All of the TPS-varieties produced several tubers per seedling, with an average of 11.4 tubers per plant.
- More than 82 % of the tubers produced in pots were usable for the production of seed or ware potatoes.
- The average tuber yield per botanical seed by varied between 71.9 and gram.

Since the commercial use of TPS-varieties is based on the seeding in the open field or in transplant beds, the results from these seeding in pots are mostly of an indicative value to the potential role of TPS in the EU. The main purpose has been the production of a reasonable quantity of seedling tubers to enable the field assessment to take place.

5. THEORY AND APPROACH TO THE ECONOMIC ASSESSMENT OF TPS[1]

5.1 Introduction

The main objective of this study is to determine whether "The use of TPS technology will bring economic benefits to the potato industry of the European Union" (H_1), or whether "The use of TPS technology will bring no economic benefits to the potato industry of the European Union" (H_0) This specific problem is no more than a variant of the more general question that is frequently put to economists namely "What will be (or has been) the economic impact of a new technology ? ".

In order to address either this general question or the specific one about TPS technology, it is essential to find or develop a methodology that can measure and assess the impact of the new of technology. The literature in economics and agricultural economics contains a vast amount of publications about the nature, creation, development, dissemination and impact of new technologies (e.g. Mansfield et al 1993; Hayami et al 1985; Stoneman 1983; Williams 1973). This chapter briefly reviews the main methodologies that have been developed for the impact assessment of new technologies. Based on this review the methodology (mathematical modeling) that is deemed most suitable for the assessment of TPS technology will be identified. Some of the existing economic potato models are reviewed, which led to the conclusion that a purpose-build model will be needed to tackle the specific problem of TPS assessment in the EU.

Defining the phenomenon of a new technology is not as straightforward as it might appear at first sight. According to the basic theory of supply and demand, a new

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[1] This chapter includes material from the poster paper "A modeling approach to the impact assessment of new technologies in the European Potato Industry; the case of True Potato Seed ". by Renia,H.,Anderson,J.L.,Dent,J.B., Lilwall, N.B.,(1996), presented at the VIII EAAE Congress, Edinburgh, 3-7 September,1996.

technology is successful when it enables the producers of a certain good to increase their overall output, whilst maintaining or even reducing the overall input per unit of production (Heertje, 1977). Many new technologies can be described accurately in this way. The green revolution offers a textbook example of this type of new technology, since the total food output increased dramatically without a matching increase (per unit of production) in the utilization of labor or land (Gleaser, 1987).

Problems with this definition arise when a new technology enables the production of goods that have never been produced before. The new technology that produced the "Walkman" created its own market with totally novel supply and demand functions. In such a situation it becomes impossible to compare "old" versus "new" technologies, and study the supply-and-demand curves of "before" and "after" the arrival of the new technology. Further problems arise with the concept of "new". The invention of the telephone was definitely a form of new technology in the late nineteenth century. To most people in western Europe it has long become an old technology and basic commodity. It is even debatable how long the cellular phone can still be considered as a form of new technology. A 1996 advertisement by international telephone companies claimed that approximately 50 % of the world's population has never ever made or received a telephone call in their life. To these people the telephone will remain a "new" technology for many years to come, and the potential impact of the telephone on their lives is still being studied (Domatob et al., 1996)

The economic assessment of new technologies can be undertaken at two points in time. Either before their introduction (ex-ante) or after their introduction (post-hoc). Post-hoc assessments have the tremendous advantage that they can use much more factual information about the actual impacts of the new technology. Ex-ante assessments are by definition more difficult because of the lack of factual information, which makes them heavily dependent upon the best estimates by experts in the field. Nevertheless ex-ante assessments are greatly sought after, especially by policy-makers and investors.

5.2 Theories on the assessment of new technologies

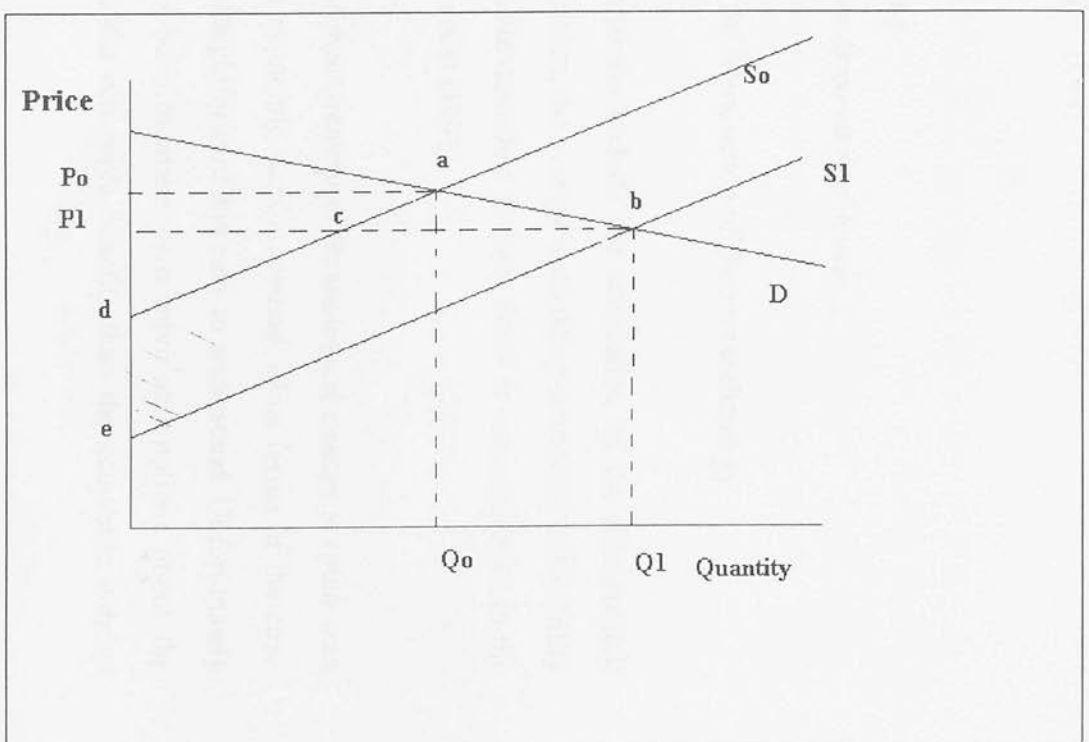
5.2.1 Consumer surplus method

The foremost method for the assessment of new technologies is by means of the economic surplus model. Starting from a situation in which there is a static partial equilibrium, the introduction of a new technology will cause the supply curve to shift towards the right. Thus a new equilibrium will be reached at a new price and a new quantity. This shift is illustrated by Figure 4.2.

The total benefits of the new technology to society can be obtained by measuring the area that is enclosed between the price-axis, the demand curve and the two supply curves. This is represented by the shaded area in Fig. 4.2. The total benefits can be subdivided into the consumer surplus (the area enclosed by the points a, b, c) and the producers surplus (the area enclosed by the points b, c, d, e).

The economic surplus model can be extended to include many other aspects of the wider economy such as the effects of trade, demand shifts and pricing policies. The real-life execution of the economic surplus method is far from simple. Accurate formulae to express the supply and demand curves for any particular commodity in any particular market are mostly difficult to obtain (Alston,1995).

Figure 5.1 Economic value of a New Technology



With :

P_o = Equilibrium price before the introduction of new technology

P_1 = Equilibrium price after the introduction of new technology

Q_o = Equilibrium quantity before the introduction of new technology

Q_1 = Equilibrium quantity after the introduction of new technology

5.2.2 Cost Benefit Analysis

The method of cost benefit analysis differs from the consumer surplus method, in that it also includes the costs that are associated with obtaining and introducing a new form of technology. It is based on the measurement (or estimates) of the annual expenses and revenues that are the result of a new type of technology. These annual benefits and costs are subsequently discounted over time, and combined into a single expression of net benefits.

The calculation of the Net Present Value (NPV) is probably most familiar form of cost benefit analysis. The NPV of a new technology with a life span of 25 years, can be calculated with the following formula:

$$\mathrm{NPV} = \sum_{y=1}^{y=25} \frac{(By - Cy)}{(1+i)^y} + \frac{.....}{......} + \frac{(By - Cy)}{(1+i)^y}$$

With

By = Benefits arising in year y

i = the prevailing interest or discount rate in year j.

Cy = Costs arising in year y

y = number of years since the introduction of the new technology

Other forms of cost benefits analysis include the calculation of the (discounted) payback period, internal rate of return, the average accounting return and profitability index. These and other methods are described in more detail at various places in the economic literature such as Ross et al (1991).

The cost-benefit approach to the measurement of technological change is often seen as a attractive alternative to the economic surplus method. Most forms of the cost-benefit approach are relatively straightforward and easy to understand. Unfortunately all the cost-benefit calculations have to make even more assumptions about the market, and the distribution of the economic benefits than the economic surplus method (Alston,1995). This is because the cost-benefit approach is implicitly based on the economic surplus method.

Notwithstanding these problems, cost-benefit methods are widely used to obtain an "indication" of the value of new technologies. One of the rare studies in which an attempt was made to assess the value of TPS technology, was done by using the cost-benefit approach (Khatana et al 1996)

5.2.3 Econometric modelling

Another method of assessment - also derived from the consumer surplus method - is by means of econometric models. Provided that sufficient empirical data can be obtained, such models can produce a useful estimate of the effect and value of a new technology.

Examples of econometric models that have been constructed for this can be found at various places in the literature; Donovan et al (1992) used it for the post-hoc assessment of new technologies in the South African Sugar Industry, and Farquharson et al (1991) used it for the ex-ante assessment of the new twinning technology in the beef industry.

Some major problems of the econometric approach are the requirement for large data-sets, which are often difficult to obtain, and the inherent limitations of the model for its use in other markets or commodities. More back-ground information about the econometric approach for the assessment of technologies is provided by authors such as Chambers (1988).

5.2.4 Mathematical modeling

Another approach to the assessment of new technology is by the use of mathematical modeling. Linear Programming (LP) offers great opportunities to understand and asses the impact on the use of alternative activities (e.g. new technologies) in the context of agricultural economy (Winterboer,1973; Dent et. al., 1986). The explosive increase in available computer-capacity, accompanied by the decimation of computer cost, has been a great stimulus to the application of LP Models. Nowadays large LP-models can be constructed with relative ease and deal with very large numbers of alternative options and limitations. A good example of the mathematical modeling approach is presented by Griffith et al. (1995) in the assessment of the impact of the technology for large lean lamb production.

Unlike the econometric approach, the LP-method is also capable of providing a concurrent assessment of the effect on a number of resources, some of which can not be properly valued (environment, pollution) otherwise. Furthermore LP-models can be expanded so as to ensure that various objectives of a new technology such as risk, farmers income, regional income etc. are properly assessed. This technique, known as Multiple Criteria Decision Making, is well documented in the literature (Romero et al 1989). The approach of mathematical modeling has the added advantage that the processes of introduction and adoption of new technologies can be simulated very well by means of dynamic programming models. An example of the dynamic modeling approach in the simulation of replacement decisions in animal herds is given by Jalvingh et al. (1992).

5.3 Limitations to the assessment of new technologies

All the assessment methodologies, are handicapped in their application by some or all of the following uncertainties that are inherent to new technologies:

1: New technologies are generated at a cost to society. Scarce resources have to be sacrificed in order to produce a new technology. Generally this takes place in the form of research and development costs, or through the buying or leasing of intellectual property rights. These research costs are often substantial. The expenditure on world-wide agricultural research for instance amounts to $ 9 billion per year.(Eicher, 1994). Research itself is an uncertain and risky activity in terms of results and revenues. Thus the providers of new technologies will demand compensation for the direct costs incurred in developing a new technology as well as a share of the costs of developing unsuccessful technologies. Since research is mostly carried out over a number of years and is interrelated and interdependent with scientific developments in other disciplines, the allocation of the true costs becomes very difficult. The problems surrounding the generation of new technologies have been described in various places in the literature such as Alston et al (1995), Coombs et al (1987), Stevens et al (1988).

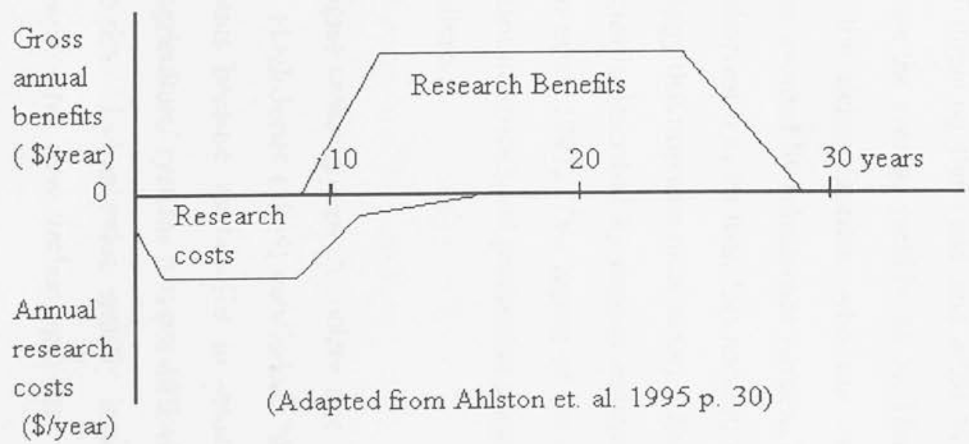
2: Producers who (rationally) would benefit from a new technology, often require a considerable amount of extension before they choose to adopt it. New technologies that are not being used, or not being used correctly, will end up having only a sub-optimal value. Agricultural extension has long been recognized as a most important aspect of agricultural and economic development, and has since grown into a separate discipline (Ban, 1988). The extension costs that are needed to transfer the new technology to the farming practice are often very difficult to quantify, since it is interwoven with other forms of extension. Nevertheless in an assessment of new technologies, the costs of extension should be taken into account.

3: The benefits from a new technology often spread quickly, both geographically as well as vertically into different markets. Further improvements and innovations of the new technology may lead to knock-on benefits in other areas. A good example of this can be found with the new technology of in vitro-fertilization of mammals. This technology in animals has led to far-reaching changes in the production systems of several animal species, which are taking place in several dozen countries. To assess the benefits of a this new technology like inevitably has to result in a "best estimate" rather than realistic measurements. As a result of the above, the impact of new technologies on international trade relations can often be significant, and very difficult to quantify (Dosi et al., 1990).

4: The benefits of new technologies generally appear over several years, with periods of 10 to 20 years not being exceptional. When the time that is needed for research and development of the new technology is included, it is easy to end up studying costs and benefits over a period of 30 years or more. Fig. 4.1 illustrates the development of annual costs and benefits for a hypothetical technology.

A major problem in the assessment of costs and benefits over such a prolonged period, comes from the many other changes that will take place on such a time scale. Policies, prices and consumer preferences are just some of the factors that are subjected to great variations, even without the impact of a specific new technology. After a few years it becomes more and more difficult to attribute either the costs or the benefits to only one form of new technology.

Figure 5.2 Net Benefits of New Technology over time



(Adapted from Ahlston et. al. 1995 p. 30)

5: The switch to a new type of technology causes adjustment costs. The value of existing technology will have to be depreciated (sometimes instantaneously), and direct costs will be through factors such as staff training and the purchase of new equipment. The change-over costs can be substantial. With respect to the economic benefits of a technology such as TPS, the head of agronomy of the AVEBE-starch potato co-operative stated that: "A gross benefit of around $ 1 million per year would not be worth the trouble of changing the current system and retraining some 6000 farmer members" (Rus,1995). The change-over costs - although they are often hard to measure - should be deducted from the total value of the new technology,

6: New technologies often carry a different risk from the existing technologies. This difference can prove to be of crucial importance for the adoption and thus the ultimate benefit of a new technology. A new cropping technology that promises an 80 % chance of doubling the yield and a 20 % chance of misharvest, may be expected to increase the average yield by 80 %. Thus the technology is likely to find acceptance with the richer farmers, who can carry these risks. Yet the same technology will be avoided by subsistence farmers, for whom their entire survival is at stake. Any misharvest may be their last harvest, and thus they will prefer to stick to the old technology that provides more safety. The problems related to the riskiness of new technologies is described by various authors (Loehman et al,1995; Millan et al, 1994; Shapiro et al, 1993). This aspect of the assessment a new technology is especially important in agricultural production systems whereby any failure could be also be the last failure.

7: New technologies create groups in society that will suffer from the effects of a new technology. Hugh-Jones (1969) concluded, "that technological change always leads to complaints because its benefits to some are accompanied by losses to others". Within agricultural systems it is not difficult to find examples of this aspect of new technologies. Mechanization usually leads to unemployment to manual laborers, for whom the new technology can mean the start of long term unemployment. Alston et al (1995) proposed that in an ideally rational society those who at first lose out from a technological development should be compensated by those who gain from its development. Such a system of compensation would lead to a society that eagerly adopts the new technologies since it results in an overall improvement of welfare. In the absence of such compensation payments, new technologies will create additional costs to some sectors of the society, and thus should be taken into account in the assessment of its overall economic value.

8: The ultimate value of new technologies depends on many autonomous developments in society at large. For instance, the change in public perception about the ethics of the bio-industry has meant that technically excellent improvements on lay-hen-batteries have become obsolete even before their introduction. The occurrence and effect of such exogenous changes are most difficult to predict, but may not be ignored, especially in the case of ex-ante assessments.

9: The effects of not introducing a new technology can often be as important as those of introducing a new technology. Anthony et al (1991) is one of several authors who addressed the importance of understanding the future without formal research projects, in comparison to a future with research projects. It would be an oversimplification of reality to assume that a production system would not change over time without the input of a new technology. Mankind has always had difficulties in the prediction of the future, even without the impact of a new technology.

5.4 The choice of methodology

In theory any of the methodologies that are described earlier in this chapter, could have been used to asses the impact of TPS technology. Limitations of time and supporting resources necessitated the somewhat arbitrary choice for mathematical modeling.

Against the use of the consumer surplus method (as described in 5.2.1) counted the fact that accurate formulae to express the current supply and demand curves for the potato industry were not readily available. Employing this methodology would require an enormous amount of historic data and preparation time, in order to generate the formulae that would approximate the current supply and demand curves. Furthermore generating the supply and demand curves for the (future) situation whereby TPS is widely available would be even more difficult and depend heavily upon guestimates by experts.

Against the use of the Cost Benefit Analysis (as described in 5.2.2) counted the facts that (1) Little information is publicly available about the cost of generating or disseminating TPS technology. At this point in time "American style" TPS technology is available, where it came from or how much it has cost to generate is immaterial by now. These are all sunken costs. The most crucial element of the assessment for the EU potato industry is to learn whether or not it would be beneficial to employ this new type of technology with its currently know characteristics (i.e. American style TPS technology).(2) The assumptions about the various discount rates during the years of generating and using the technology have a great effect on the final result, but the values used are always arbitrary and highly disputable. Few economists can agree upon which discount rates to use for past years, and even fewer for upon the discount rates that should be used for future years.

Against the use of econometric modeling (as described in 5.2.3), counted the facts that it; (1) requires large and reliable data sets from many markets in the EU over several years, which are unlikely to be available due to the heterogeneous nature of the EU industry. Lack of data proved to be one of the major problems to Fowell et al. (1985) in their attempted analysis of potato markets in the USA. (2) would not be readily capable of providing information on the agricultural impact of TPS technology (3) would not identify which groups of land users would benefit or lose from the technology and (4) would not provide shadow prices for alternative allocations of the resources.

In favor of the use of mathematical modeling counted the facts that: (1) it allows the modeling of a great number of activities and alternatives without much extra work, once the main model has been constructed. (2) the models can be adapted with relative ease to assess the impact of other technologies (such as micro tubers and aerial tubers) to the EU potato industry. (3) the models have great flexibility, since they allow for the study of the impact of a technology at various levels of detail.

The use of mathematical modeling is not without problems. The problems associated with a paucity of data that counted against the use of other methodologies will to some degree also affect suitability of mathematical modeling, although it is hoped to a much lesser extent. Another important factor in the choice to use mathematical modeling was the fact that the University of Edinburgh provided abundant technical support for the creation and usage of mathematical models. Hence it was thought that proportionately less time would be needed for the construction of the specific methodology, and more time could be allocated to the application of the methodology.

5.5 Existing potato models

A logical starting point for the construction of a model to simulate the impact of a new technology on the potato industry, is to look at what other scholars have published so far on this subject. A literature search in the CAB-abstracts over the 15-year period from 1982 - 1996 shows that publications on potato models are generated at an average pace of almost 90 per year. Publications of potato models that also incorporate economic aspects are more rare, although on average more than a dozen are produced each year (See Table 5.3).

Table 5.1 Results of CD-ROM search (CABI) for economic potato models.

Period	Potato Models	Economic Potato Models	%
1982-83	114	23	20
1984-86	226	44	20
1987-89	245	38	16
1990-92	288	47	16
1993-95	358	50	14
1996	98	14	14
Total 1982-96	1,329	216	16

It is clear that there is no (quantitative) shortage of potato models. Biophysical models in particular are built and used in great numbers, to address specific and general problems in the understanding of potato cultivation. Since these models generally do not incorporate the economic volatility of the market place, most of them fall outside the scope of this study. The multitude of these models can be attributed to the relative ease with which the potato plant can be modeled, and the global importance of the crop as a source of food supply.

Excellent reviews of biophysical potato models can be found at several places in the literature, such as Kabat et al.(1995) and MacKerron (1992). Still, there is one area of the biophysical models in which there is a great lacuna. Virtually no simulation models have ever been constructed or described with respect to the germination and first weeks of growth of botanical potato seeds (Lommen,1996).

The main interest of this study is towards economic potato models that incorporate aspects such as new technologies, mathematical modeling, the seed potato sector and the European Union. These elements were found in the following studies;

new technologies

Walters et al. (1988) simulated the impact of new seed technologies on a variety of crops (including potatoes) in two Peruvian regions. They also used LP-modeling, but their main emphasis was on the effects of credit availability to small farmers. Moxey (1991) constructed a biophysical simulation model to estimate the economic value of a new technology to prevent frost damage in maincrop potatoes. He based his model on single enterprise gross margins, which would be practically impossible for the construction of an EU-wide model. Lamont (1992) studied the way in which the Dutch seed potato industry develops and introduces new products, and concluded that much of the success of these new products is correlated with the strong position the Dutch hold in international markets. Fuglie (1995) described a multi-market model to estimate the welfare benefits from improved storage technologies in Tunisia.

mathematical modeling

Several mathematical models have been reported which optimize the allocation of irrigation water for potato cultivation (Feinermann et al., 1983; Sondge, 1984). Other frequent uses of mathematical models appear with regards to rotation issues (Lazarus, 1983; Warner, 1987; White,1991) and potato processing issues (Orr et al., 1983). More recent is the appearance of mathematical models in which the optimum balance between farm income and the environment is sought (Bretas et al, 1990; Schans 1991). Only the study by Greig (1988) came close to the type of model that will be needed for the EU potato industry. They constructed a mathematical model to optimize the production and utilization of potatoes in nine US states. Their models proved to be highly sensitive to changes in cost of production, freight rates, price discounts and wastage margins. The impact of price discounts especially proved to be a large and unavoidable influence on the outcome of the optimal solutions.

seed

Rhoades et al. (1983) provide a model for solving problems related to the storage of seed potatoes in Peru, which bears few if any similarities to the situation in the EU.

Meijers' (1983) LP decision model for the production and sale of Dutch seed potatoes appears more attractive. Unfortunately the potential of this model as a building brick for the model on TPS is very limited since it only deals with the situation in the Netherlands in the 1968-1977 period. Nor does the model take account of the reaction of other players in the EU industry to the choices that are optimal for the Dutch seed industry.

The model by Cook (1984) simulated the ways in which the Northern Ireland seed potato industry should react to economic and technical changes, and is limited in its applicability to the situation in Northern Ireland. Finally Lamont's (1991) comparative model of the seed potato industries of the Netherlands and Northern Ireland, provides an insufficient basis for an EU-wide model.

EU-countries

Two models were developed with the specific aim of analyzing the UK situation. White (1985) analyzed the early potato market in the UK, albeit when it was still being regulated by the Potato Marketing Scheme, and thus the supply and prices in the market where regulated. Ennew (1988) developed an econometric model for the maincrop potato market in the UK, but again under the influence of the Potato Marketing Scheme. A model on the way in which margin between farm- and retail prices are formed in the Spanish fresh potato markets was described by Barallat et. al. (1987). A more hypothetical model of the whole of the EU potato industry was made by Nuppenau (1987) in his projections of the effects of some form of price stabilization.

5.6 Conclusions for the building of a mathematical model

Several methodological options exist to carry out an ex-ante assessment of a new technology. All of them are handicapped by the uncertain side-effects that are inherent to new technologies. For the assessment of TPS technology the use of mathematical modeling was favored above the other options, because of the greater flexibility of this method.

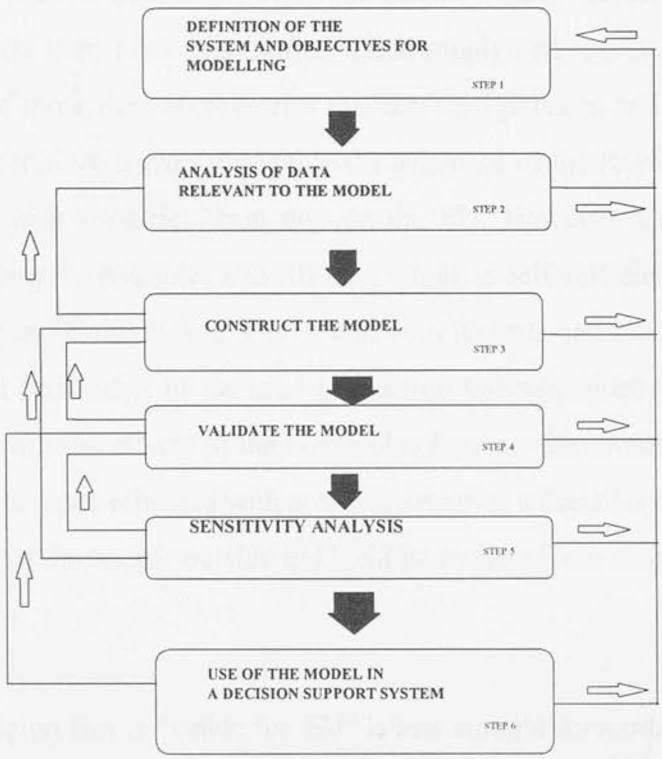
The idea that it could be possible to modify an existing model of the EU potato industry, to assess the impact of TPS technology had to be abandoned. None of the economic potato models, that were published between 1982 and 1996 included all of the elements that are essential for the purpose of this study. Therefore it was necessary to construct a purpose-built model which will be described in detail in Chapter 6.

6. THE DEVELOPMENT OF A MATHEMATICAL MODEL FOR THE EU POTATO INDUSTRY

6.1 Introduction

This chapter describes the developmental construction process of a Linear Programming (LP)-model of the EU potato industry that has been purposely built for the assessment of TPS technology. Many studies described the building and use of models in the fields of agriculture and economics, (Dent et al, 1979; Williams, 1993; Neal et. al, 1976; Norton et al 1980, Hazell and Norton 1986). All such publications describe model building as an iterative developmental process, that requires frequent revisions of previous stages. Dent et. al (1979) described the following 6 stages (Fig. 6.1)

Fig. 6.1 Development stages of model building



This chapter will discuss the activities that have been undertaken for the steps one up to three (model construction). Chapter seven deals with the validation issue and sensitivity analysis, whilst chapter eight provides the results of model application in a number of technology uptake scenario.

Defining the EU potato industry

The first step in the modeling process consist of defining the system that is being studied and the objectives for modeling. The system under investigation here is the EU potato industry and according to Norton et al. (1986) " *A complete sector (or industry) is normally defined by complete coverage of the commodity balance equation for related products by representation of all supply sources and all uses of the products*" .

In the case of the EU potato industry that should include modeling of the potato industries of more than a dozen countries which supply early potatoes to the EU, and the modeling of more than 60 countries that use seed potatoes and processed potato products. It is certainly correct to include the existence of the (current and potential) trade relations with countries from outside the EU. However a certain degree of simplification may be possible. The EU as a whole is self sufficient in its needs for potatoes (European Commission, 1994), and both imports and exports account for a relatively small percentage of the total production volume. Since the main focus of this study lies with the effects of the new technology on the countries inside the EU rather than on the trade relations with non-EU countries a decision was made that the potato industry of the world "outside EU" will be modeled as a single point of supply and demand.

Defining the region that is "inside the EU" is less straight forward. The accession of new member states to the EU means that the geographic area under investigation has increased significantly, with the joining of Austria, Finland and Sweden at the beginning of 1995. Furthermore, a considerable number of other European countries have indicated the desire to join the EU before the year 2000.

One of them, Poland, has a domestic potato industry that is of similar size to the whole potato industry of the EU-12. The obvious question arises whether an ex-ante assessment should incorporate potential increases of the membership of the EU, or not. In principle the answer must be yes. In practice however it will be impossible to predict which countries will enter the EU when, and under what (still to be negotiated) conditions. Thus any model that incorporates such future expansions, will at least have an uncertain boundary.

For this model the choice has been made not to include potentially new members of the EU. This exclusion will have to be kept in mind during the final assessment of the modeling results. If TPS-technology is economically beneficial to the current EU-potato industry, it may be presumed to be, at least as, beneficial to an enlarged EU. New members will only take up this new technology, if it is beneficial to them, otherwise their costs of production will remain at their current level. But on the other hand if TPS technology is not of economic benefit to the current EU- potato industry, it may still prove to be beneficial within an enlarged EU.

Austria, Finland and Sweden, although they became members of the EU during the period of modeling, have not been included into this model. The rationale for this is twofold; Firstly these countries have only recently joined the EU and thus it is likely that their domestic potato industries are in a transitionary phase of integration with the EU-potato industry as a whole. A more stable level of integration may not be reached for some years. Secondly, the availability of useful data from these countries is limited. There have only been two productions seasons (1995 & 1996) under the condition of the EU-member states, and data of the previous production seasons excludes all the effect of access to the common market. It is unlikely that this exclusion will have a great impact on the final results. Based on figures for 1993, these three countries would have increased the volume of the EU-industry by less than 6 % (Eurostat, 1995).

Regions that legally belong to the EU, but are not located within Europe (e.g. French Guyana, Reunion and Guadeloupe) have not been included in the model. Their potato industries are either very small or non-existent, and henceforth their contribution to the EU potato industry is assumed to be minimal. The EU that results from these exclusions consists of the following 12 countries; Germany, France, Italy, Belgium, Luxembourg[1], The Netherlands, Denmark, the United Kingdom, Ireland, Spain, Portugal and Greece.

As a result of the above the EU potato industry may be defined as the supply and utilization system of potatoes that are either produced, utilized, or both, in geographical region of these twelve member states of the EU.

Defining the objectives

The wider objective of this modeling exercise is to assess the impact of a new technology of potato propagation on the EU potato industry. The specific objective has been stated in chapter 1.3, namely to test the hypothesis that "The use of TPS technology will bring economic benefits to the EU potato industry".(H0) against the alternative hypothesis that it will not bring benefits (H1).

For this purpose TPS technology will be defined as a form of potato production that utilizes botanical potato seeds to produce seed potatoes (grade EEC1) that can either be used for the production of another generation of seed potatoes (grade EEC2 and EEC3) or for the production of early, ware or starch potatoes. The modeling of TPS utilization will be based on the American style of TPS-utilization, i.e. with direct seeding and the production of tubers that are capable to meet the quality standards of markets in industrialized countries. This definition implicitly excludes the use of

[1] Consistent to most EU statistics, Belgium and Luxembourg have been represented as one country. Although the total potato industry of Luxembourg is very small, there are good reasons not to exclude it all together from the model. Luxembourg plays an important role in the production of certified seed potatoes. In absolute measurements, its seed potato area is equal to that of Portugal and Greece, and almost half that of Belgium (VBNA, 1995)

TPS-varieties that have been bred by CIP (since they are not aimed at the needs of industrialized countries) or the use of botanical seeds by means of transplanting or seedling production in nursery beds. These last two forms of TPS use are more labor intensive, and hence more expensive than the direct seeding of TPS. If the direct seeding of TPS proves to be economically profitable, than it would be justified to further investigate the potential of more expensive forms of TPS utilization. On the other hand if the technology is not economically viable with the use of direct seeding, than there is no point in investigating the potential of more expensive forms of utilization.

The economic benefits from the use of TPS technology will be defined as the release of scarce resources that will no longer be needed in the potato production process, due to an alternative allocation of resources, that does not affect the previous total level of production.

It is important to note that the above hypothesis lacks any reference to the time element, which makes it theoretically impossible to either prove or disprove it. Antagonists of the technology may calculate the costs and benefits during the first year of utilization and rightfully conclude that the costs outweigh the benefits. Proponents of the technology may include a "nightmare scenario" whereby the conventional seed sector is hit by a disease that is not transmittable though the botanical seeds, and hence claim the economic superiority of their technology.

There are several ways to incorporate the time element into the hypothesis e.g.; (A) The benefits of the technology can be measured over its expected life span, (B) The total benefits of the technology can be measured over a fixed time period like the first five years after its introduction, (C) The benefits can be determined for a representative year, in which the technology is assumed to be readily available without taking into account the gradual increase of the benefits that takes place during the first years after introduction.

From many points of view the preferred option would be to assess the impact of the new technology for the whole of its economic life span. Arbitrarily the choice can be made to set the life span of the TPS varieties at 25 or 30 years, as a reflection of the current periods for which potato plant breeders rights are given in the EU (SSPDC,1996). However several authors such as Walker (1994) mention the fact that quite a number of commercially important potato varieties have demonstrated a life span of more than half a century, whereas other varieties do not last half as long as their breeders' rights. Therefore predictions of the expected life span of a new variety can not be made with a great degree of certainty. For this reason the option of assessing a "life span" period of the technology has been discarded.

The second option, to limit the assessment to the reasonably foreseeable future with a time horizon of say five years, has its advantages. If TPS technology proves to generate economic benefits during the first few years of its application, than it can safely be assumed that it will also generate a positive net benefit during the remainder of its life span (no matter how long or short). Furthermore a better estimate about the situation in the near future than the distant future can be made. A caveat for the potato industry however are the many years of multiplication that are currently needed by the clonal seed sector. Wide spread availability of cheap botanical potato seeds will most likely lead to some years of oversupply of potato planting material and thus a breakdown of prices. The suppliers of clonal seed have already incurred several years of production costs and suddenly find themselves with a perishable product in a finite market. Since it is nearly impossible to make correct assumptions about the introduction pattern of TPS technology as well as the reactions of the clonal sector, the option to focus on the first few years after the introduction also has been discarded.

The third option is to study the impact of TPS technology during "a representative year" under the assumption that potato producers can chose to use either the new or the old form of technology, without the burden of the initial start up and change over costs. This option has the advantage that is provides the industry with a good indication of the size of economic benefits that may be expected from this new technology. If the expected annual benefits in a representative year are in the same range, (or substantially higher) as the expected total costs to develop and change over to the new technology, than further and more detailed research is warranted. On the other hand if the annual benefits do not come close to the expected cost of establishing the TPS technology, the industry as a whole would be better of to allocate its R&D funding towards other forms of improvement.

It is thought that the EU potato industry will initially be best served with an assessment of the expected annual benefits of TPS technology in an assumed steady state situation, i.e. a representative year. Such an assessment can then be used as guidance for the discussion, for example, of whether or not to lift the import restrictions on TPS from Chile, and whether or not more research should be done to adapt TPS technology for utilization in the EU. Hence the scope of the model has been limited to "a representative production year[1]" of the EU potato industry. The assessment of the benefits of the technology during a representative year also implies that the cost of phasing in TPS-technology and depreciating the old technology will not be taken into account.

The modeling development that will be followed in the remainder of this chapter can be represented by Fig. 6.2

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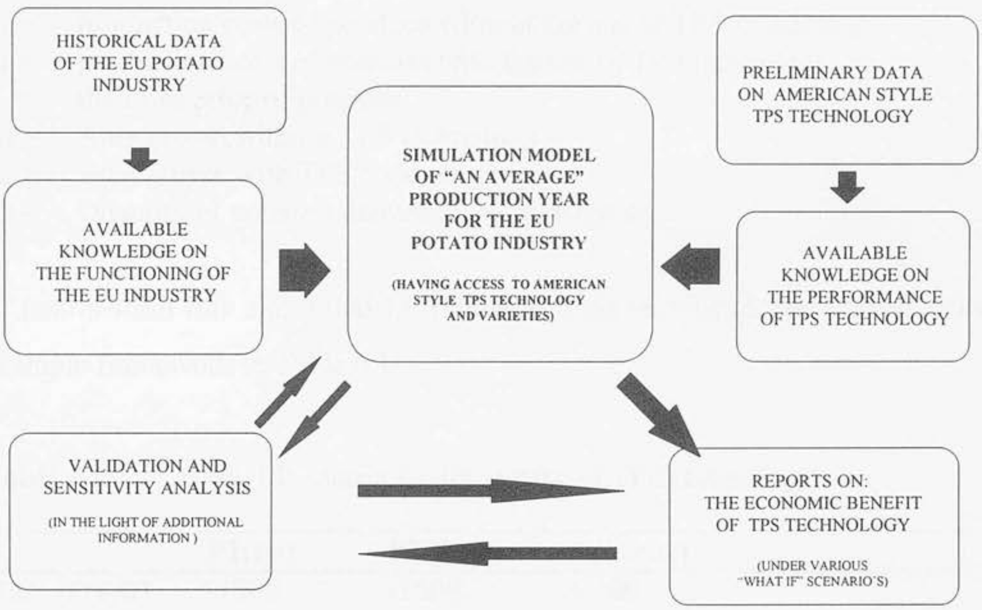
[1] Identifying a representative year is not without problems. Years with an over supply, balanced supply and under supply of potatoes follow each other without any regularity since they are the composite result of climatic conditions during the growing season and farmers reactions to past prices and expected future prices. For this study a representative year is meant to be a year in which supply and demand are in balance, thus excluding the years of under or over supply which can never be the conscious aim of either producers or suppliers Thus the representative year is not the same as the arithmetic average over a period of several year.

Fig. 6.2 Development of a model to assess the impact of TPS technology



6.2 The principle use of LP-modeling for the assessment of new technologies

The essential choice by the EU-Potato Industry as a whole to either utilize, or not to utilize TPS technology can be easily modeled as an LP-problem. The industry as a whole attempts to optimize its own goals (e.g. profits) by carrying out certain activities such as potato production, transplantation of seed tubers etc., which are subject to a number of constraints such as the availability of land and a finite consumer demand. In pursuing its goals the industry can chose to use: either (1) the conventional technology for potato propagation, or (2) TPS-technology, or (3) a combination of the two technologies.

If the EU-potato industry could be represented as a single producer, with a single piece of land, a single product and a single customer, the basic LP-formulation (assuming profit maximization is the objective) for the assessment of TPS-technology can be as follows;

Max (Industry profit) = $- P_1 X_1 - P_2 X_2 + S X_3$

Subject to constraints like the availability of land and demand for potatoes.
where:

P_1 = production costs of potatoes without the use of TPS-technology,
P_2 = production costs of potatoes with the use of TPS technology,
S = the sales price of potatoes
X_1 = Area grown without TPS technology
X_2 = Area grown with TPS technology
X_3 = Quantity of potatoes demanded by consumers

In matrix-form this simplified LP-problem could be written and solved within the example framework in Table 6.1.

Table 6.1 Basic LP-Matrix for the uptake of TPS technology.

	P1(ha)	**P2 (ha)**	**S (tonne)**		
Max. *(Profit)*	-1500	-1600	+ 100		
Subject to the Constraints of:					
Supply	-30	-30	1	<=	0
Demand	0	0	1	=	42,000
Land	1	1	0	<=	1,500

where:

P1 = production without the use of TPS-technology is at a cost of £ 1,500 per ha.
P2 = production with the use of TPS technology is at a cost of £ 1,600 per ha.
S = the sale of potatoes, at a price of £ 100 per tonne.
Supply = yield of potatoes in tonne/ha using either technology
Demand = consumer demand for potatoes is set at 42,000 tonnes
Land = land available for potato production is 1500 ha.

The maximum attainable profit for the industry as a whole is primarily constrained by the fact that the demand for potatoes is finite. In this example, the optimum solution (profit) will be achieved at the production level of 42,000 t of potatoes without the use of TPS technology, using an area of 1400 ha. (X_1 = 1400 , X_2 = 0 X_3 = 42,000). At this point the total profit will be £ 2.1 million. However, if all the potatoes where produced with the use of TPS technology, (X_1 = 0 , X_2 = 1400 X_3 = 42,000) the industry profit would only be £ 1.96 million. The opportunity of using

TPS technology in the latter case would be £ 140,000 per year.

If however the cost of P2 were £ 1400 (£ 100/ ha less than that of P1), whilst the yields of production methods P1 and P2 remain unchanged, the industry will optimize its profits by switching to activity P2. (i.e. using TPS technology). In which case the profit would be £ 2.24 million. In the situation that both the yields and costs per hectare were for P1 and P2 are equal, there will be no financial benefit in using either type of technology instead of the other.

6.3 Developing an ideal model

The ideal model of the EU potato industry would be capable of answering all the potential questions that may arise at all the different levels of detail, by all of the stakeholders in the industry. For the scenario of adopting TPS, it would be able to inform the small holder farmers in Portugal how their profits will be affected, the British consumer of imported early potatoes from Italy how much cheaper the potatoes would get, and the Dutch seed producers how much smaller their export market would become. The oversimplified model of the EU potato industry that was introduced in Figure 6.3 is clearly not capable of solving many different types of "what if" questions.

The opposite of this simplified model would be the construction of an LP-model that takes account of all the known factors at the greatest level of detail, such as: the real number of potato producers (>1 million), the number of European potato varieties (600+), the number of customers (370 million) and the price variations throughout the year (365 days).

Such a modeling approach would necessitate an LP-matrix of several billion activities, and would be limited by an equal dimension of constraints. Even a (less-exhaustive) model that is based on say 2 types of potato production (old and new technology), plus the actual number of producers, plus the actual number of varieties would require some 1.2 billion columns. It is obvious that any model of such dimensions will be plagued by practical problems, and because of the inherent data problems can hardly claim to be an intelligent approach. Furthermore the limitations of available time to undertake a Ph.D.-study project, make is necessary to build a matrix of intermediate dimensions, that will be relevant and realistic in data demands.

Since this model constitutes the first (documented) attempt to assess the impact of TPS technology in the EU, it should strive to be able to answer the most important questions. In this respect the general questions affecting the whole of the EU industry are deemed more important than specific questions that are only relevant to a subsector of the industry. At a policy level the first question that needs answering will be "What will be the effect if the EU follows the example of the USA-government, and lifts the import ban on cheap botanical potato seeds from elsewhere ?" Hereby it is implicitly assumed that potato producers will base their choice to use TPS technology only on their profitability, and no other (e.g. cultural) grounds. Further questions would deal with issues like , which groups are likely to benefit from such a change, and which groups will lose out and in which regions will the technology have the most impact ?

The model for this study will be constructed with the specific aim of answering these general type of "what if" questions. Special interest groups who find that the model is not capable of addressing their particular needs, will be able, with relative ease, to modify this basic model to make it suit their needs. Provided of course that they can provide the additional data that is necessary to carry out the modeling modifications.

Two approaches can be followed to create an LP-model of intermediate dimensions. One can start with the smallest observable units (e.g. individual potato producers and consumers) and aggregate them into groups which consists of reasonably homogeneous units. Where possible (or necessary) these groups can than be aggregated again into larger groups of more or less homogeneous content. The problem with this aggregation approach is the need to collect a great amount of data at a very detailed level. Data which subsequently will not be used after the units have been aggregated into groups.

The alternative approach is to expand the simplified model of Table 6.1 so that it starts to reflect a much greater level of detail. The great advantage of this approach is that it is much easier to maintain an overview of the model as a whole, and that less data will be required. Therefore, this second approach will be followed.

Two ways of improving the level of detail will be discussed in this section, namely those according to place and time. The greater levels of detail for the model activities and constraints will be discussed in the Sections 6. 4 and 6.5 respectively

<u>Enhanced detail according to geography</u>

Chapter two demonstrated the distinct differences in the potato industries of the EU-member states, which makes it logical to enhance the model according to individual countries. Strong arguments can be made that a subdivision at this level is not sufficient to provide an accurate representation of the industry. Firstly, because some of the national industries are hardly comparable in size. The Irish potato industry for example has only 6 % of the volume of the German Potato Industry, thus the error margins in the data for one of the larger countries might be as big as the total industry of a smaller country.

Secondly, there is clear evidence that the performance of potato industries varies greatly within each country. The differences of yield and potato production between regions in an EU-member state may be as large as those between member states. The German Bundesland of Lower-Saxony alone has a potato industry that is larger than that of twelve other Bundesländer combined (ZMP,1995). Unless the model acknowledges regional differences within countries, it will be unable to adequately identify the different regional responses to a new technology.

A preferred subdivision for EU countries is that at NUTS-level. Eurostat developed the NUTS-system (Nomenclature des Unites Territoriales Statistiques) which divides the EU countries into well defined and logical statistical units (Eurostat, 1992). These units mostly reflect a homogeneous climate and population, and often, but not always, a homogeneous similar soil type. (MacKerron,1992). Several simulation models for agricultural production systems in the EU have been based successfully on the NUTS-classification: e.g. Van Lanen et al, (1992), Koning, et al. (1995), Rabbinge, et al. (1992), MacKerron, (1992).

The NUTS-classification system consists of 71 regions with the 12 member states, at NUTS-1 level, 183 regions at NUTS-2 level and 1044 regions at NUTS-3 Level. (Eurostat, 1992). For an initial assessment of the effects of TPS technology it appears sufficient to subdivide only up to the NUTS-2 level. If a greater level of regional detail is required, then the LP-matrix can be extended to accommodate a greater number of NUTS-regions, by the addition of activities and constraints at the NUTS-3 level.

Unfortunately the idea to expand geographically up to NUTS-2 level proved unworkable in reality since the EU only publishes potato statistics at the NUTS-1 (i.e. national level). Only the statistics from a few national sources -infrequently-publish potato data at a NUTS-2 level, but without constancy on all activities that contributed to the national potato industry. Since the necessary data could not be obtained at a NUTS-2 level, the model only recognizes the differences between NUTS-1 regions, which in fact are identical to that of country borders (for this study Luxembourg is included into the NUTS-1 of Belgium).

Enhanced detail according to time

The supply volumes and sales prices of potatoes can vary considerably during one production season of 12 months. For most regions production is limited to a couple of months during the spring/summer, whereas the consumption is spread more equally throughout the year. The sales price of potatoes vary from one month to another, in order to reflect the added costs of storage and storage losses incurred, as well as the arrival of a new harvest

The idea to expand the level of detail for the model into monthly or quarterly periods had to be abandoned. Too little data could be obtained, from too few countries to provide a reliable picture of the quarterly (even less the monthly) changes in the potato industry of the base year (1991) [or any other year for that matter]. Even the data for the whole year can lead to a considerable amount of confusion, since the data representations are not consistent throughout the EU. Some countries report on the situation of their domestic potato industry on the basis of calendar years. Others follow the physical production cycles and report on periods that run from spring to spring. Additional confusion exists about the definition of certain types of potatoes. The December harvest of late maincrop-potatoes in Spain or Greece can be consumed as extra-early potatoes by customers in northern Europe.

The absence of reliable information about the existing situation on a quarterly basis, makes it a futile exercise to try and model in periods of less then one year. The model is built in such a way that the total demand for potatoes in the 1991 calendar year will be supplied by the production during the 1991. This is factually not correct. Especially in northern Europe, a considerable part of the potato demand will be met by potatoes that have been produced in the previous calendar year. Similarly the demand for seed potatoes in 1991 is thought to be met by the seed production during that same year. Which is not factually correct either. By doing so the model implicitly assumes that the levels of potato production and demand are equal from one year to another.

6.4 Main activities:

Multiple level modeling

The EU potato industry is the aggregate of the activities of a great number of individuals and organizations, who often have conflicting goals and objectives. Therefore the "optimal" solution for the EU as a whole might very well be in conflict with the optimum solution for a certain region or subsector. For Portuguese exporters of early potatoes it might be an optimum situation when the Spanish, Italian and Greek exports are minimized. Similarly, the consumers of early potatoes might well aspire an unlimited import quota for potatoes from North Africa, so that they can buy at the lowest possible prices.

What is optimal for one region will also depend on the current and expected activities of the surrounding regions, and vice versa. It is certainly desirable to decompose the EU industry into components that are smaller than that of the national level. Significant differences in the cost structures can be expected between larger and smaller farmers. It may also be expected that land owners and tenants adhere to quite different decision making rules in the choice of their production methods (Kutcher, 1976).

Without decomposing an industry model into different levels of decision making and optimization, "*the problem would collapse into a single mathematical programming problem, and the analogous decision making situation would be one of completely centralized planning*" (Norton et. al, 1980). It will be clear that the EU potato industry is neither centrally organized nor planned, and henceforward a multilevel approach should be employed. The technical difficulties of building and solving a multi--level model are by no means small, but they often seem minimal in comparison to the data-requirements. Since severe data-limitations were already encountered at the national level, it seemed unrealistic to build a multi-level industry model, for which the necessary data requirements could not be met.

The resulting model for this study thus becomes a single mathematical programming model (see Table 6.1) that is more normative than descriptive in character. "*This type of normative model is useful, nevertheless, for defining quantitatively the potentials of the sector- the physical frontiers of the production possibilities set-*". (Norton et al., 1980). The results of this kind of modeling will indicate what "would be possible" if all the stakeholders in the industry collaborated to achieve the most efficient overall solution. In actual fact, that solution is unlikely to be completely achieved due to individual behavior of various stakeholders.

By using a single level optimization model, it is implicitly assumed that the industry is regulated by a single decision making entity, which aims to improve the overall gross margin of the industry, without any preferential treatment to any region or sector of the industry.

Table 6.2 Overview of the LP-matrix for the EU-Potato industry.

Constraints *(by NUTS-unit and time unit)*		ACTIVITIES *(By Nuts-units, and by time)* Production *(by types of production,)*	Storage *(by types of product)*	Consumption *(by types of consumption)*	Trade *(by type of product & destination)*	sign
SUPPLY	by types of production	**S**				>
STORAGE	by types of product	**S**	**S/D**	**D**	**D/S**	<
CONSUMPTION	by types of consumption			**D**		=
TRADE	by types of consumption				**D**	<
LAND		**D**				<
Objective Function (s)	Maximize (EU gross margin)					

S= Supply D= Demand

Production activities

The EU potato industry generates many different types of potatoes (seed potatoes, early potatoes, maincrop potatoes, starch potatoes) which all incur different costs and generate different amounts of product per hectare. The differences between potato production from home saved seed or certified seed appears highly relevant. The use of (relatively expensive) certified seed leads to higher yields of ware, early or starch potatoes. It is expected that the use of TPS technology will lower the average price of certified seed tubers, and thus lead to an increase in the use of certified seed due to a reduced use of home-saved seed.

Since the production of seed potatoes of different qualities also attracts different costs and generates different yields, it seems reasonable to define separate activities for these.

A similar argument can be made to subdivide the production of certified seed according to the quality grade of seed that is being produced. Seed of a higher quality (e.g. EEC1-grade) is produced at a considerably higher costs than seed of EEC-2 grade, and produces a different yield. However, the need to subdivide into the 8 or more grades (to correlate with the years of multiplication) that are being used in some countries is questionable. The nature of clonal multiplication dictates that the volume and area of higher quality seed grades roughly decreases by some 90 % for each increase in quality. Thus the volume of the certified seed that is "two grades better" and thus better in quality, will only comprise around 1 % of area and value of the certified seed that is two grades lower. Technically it is no problem to expand the model to such an extent that it can cope with eight different quality grades for seed potatoes. The data-limitations however would dictate that such a refined model would have to be filled with hypothetical data, rather than actual data. For that reason no more than two seed grade qualities are distinguished.

The number of different ways in which TPS technology can be utilized for production of potatoes is great. This study will focus on the use of TPS by means of direct seeding, for production of high quality seed tubers (of EEC1 quality), which in turn can be used for the production of more seed tubers, early potatoes, maincrop potatoes, and starch potatoes

The total number of possible potato producing activities for each region comes to 16, plus an activity to simulate the 'non-production' of potatoes defined as "general arable production" instead.

Table 6.3 Definition of potato producing activities in the model .

Code[1]	Description
P00	Production of general arable products (not potatoes)
P11	Production of seed potatoes (grade EEC 1or EEC2) without the use of TPS
P13	Production of seed potatoes (grade EEC 1or EEC2) with the use of TPS
P21	Production of seed potatoes (grade EEC 3) from P11 seed tubers
P23	Production of seed potatoes (grade EEC 3) from P13 seed tubers
P31	Production of early potatoes with seed from either P11 or P21
P33	Production of early potatoes with seed from P 23
P34	Production of early potatoes with seed from P13
P35	Production of early potatoes from home saved seed (i.e. ware potatoes)
P41	Production of ware potatoes with seed from either P11 or P21
P43	Production of ware potatoes with seed from P 23
P44	Production of ware potatoes with seed from P13
P45	Production of ware potatoes from home saved seed (i.e. ware potatoes)
P51	Production of starch potatoes with seed from either P11 or P21
P53	Production of starch potatoes with seed from P 23
P54	Production of starch potatoes with seed from P13
P55	Production of starch potatoes from home saved seed (i.e. ware potatoes)

This level of detail will make it possible to see which types of potato production TPS technology is most likely to replace, e.g. either home saved seed (P_5 activities) or traditional seed (P_1 activities). The monetary values that are assigned to the

[1] In the model activity is represented by a three digit code, followed by a two digit country code and a two digit time code.

activities are meant to reflect the production costs (in 1000 ECU/ 1000 ha.) without the cost of the planting material . The costs of purchasing the planting material is "automatically" added because the production activity triggers the utilization of planting material that is being supplied by other activities. The benefit of this arrangement is that for any potato producing activity like P31 the planting material will be "purchased" at the cheapest source which could be either P11 or P21 from any of the 11 EU regions. (I.e. demand and supply for any activity can be met from 'pools' generated by the model from any region).

In the model not all of these activities in fact have been used for each country. The production options for early potatoes have not been included for Denmark, because that activity does not take place currently and it is thought to be unlikely that the use of TPS technology would make a difference to that. On similar grounds it is assumed that starch potato production activities will be included with those countries that are currently producing starch potatoes.

The model does not differentiate between different varieties of potatoes, or differences between skin color or flesh color. Thus, it implicitly assumes that all potatoes being produced (either clonally or through TPS) are of one variety, which is equally acceptable throughout the EU.

Demand activities

The demand for potatoes has been subdivided into five activities in each country, which are described in Table 6.4.

Table 6.4 Definition of activities utilizing potatoes.

Code	Description
C30	Consumption of early potatoes
C40	Consumption of (not processed) ware potatoes
C45	Use of ware potatoes by the processing industry
C49	Consumption of ware potatoes by animal
C50	Use of starch potatoes by the starch industry

In each country each of these activities generates a different revenue (in 1000 ECU/ 1000 t) to reflect the different market price levels in each of these markets. The consumption prices for early and ware potatoes have been obtained, or derived from EU price statistics (European Commission, 1990a). The process paid by the processing industry are taken to be the same as the national average potato price paid to farmers in the relevant region (European Commission, 1994). The prices paid for use as starch and cattle feed are taken to be 70 % and 40 % of the ware potato producers price. It is implicitly assumed that the consumers will have no preference for or against potatoes that have been grown with the use of TPS technology. The demand for the different types of potatoes can be met from either locally produced material, or from imported material, and under profit maximizing objective the cheapest form of supply will be chosen.

The values of the revenues is equal to the prevailing price in the relevant markets, before the introduction of TPS technology. This market price is seen as a reflection of the customers' "willingness to pay" for potatoes. The supply of cheaper potatoes (produced with TPS technology) means that the customer demand can be met at a lower total cost to the industry. The way in which the advantage of such a cost reduction is split between the potato producers, merchants and consumers would merit a separate study. If the outcome of the model indicates an overall cost, then it is reasonable to expect a decrease in the price that consumers pay for their potatoes, but the size of the decrease will depend more on the (existing) market power of the merchants than on TPS technology.

Trade activities

Some regions of the EU have comparative advantages over other regions with regards to the production of potatoes, which makes trade in potatoes profitable. Furthermore, there are highly urbanized regions which have a great demand for potatoes, but hardly any land to produce them. The intra community potato trade has been subdivided into six different product groups (see Table 6.5) that can be transported at a cost into 10 other EU countries , as well as into the rest of the world.

Table 6.5 Description of potato trade activities.

Code	Description
T11AB	transport of type P11 potatoes from country A into country B
T13AB	transport of type P13 potatoes from country A into country B
T21AB	transport of type P21 potatoes from country A into country B
T23AB	transport of type P23 potatoes from country A into country B
T30AB	transport of type P30 potatoes from country A into country B
T40AB	transport of type P40 potatoes from country A into country B
T40AC	transport of type P40 potatoes from country A into country C
T40AD	transport of type P40 potatoes from country A into country D
etc. etc.	

This way of subdividing the potato trade creates a total of more than 726 (6 (products) * 11(originating regions) * 11(destination regions) activities. In actual fact, not all these potential activities have been included into the model, since it was assumed that countries like Greece and Portugal, are unlikely to become net exporters of seed potatoes to other countries in the EU. Therefore, the southern European countries will find themselves curtailed in the export opportunities of seed potatoes, just like the northern European countries are restricted in their options for export of early potatoes.

Storage

In the model it is assumed that all potatoes produced are placed into storage for a period of time, during which they incur costs and weight losses. Although there are no records of difference in storage losses between traditional potatoes and potatoes produced from TPS, the storage activity has been included for both separately. In many southern European countries, the limited availability of cool storage, places a real restriction on the capacity to keep seed tubers in good enough condition to be useful as planting material in the following season. Unfortunately it was not possible to obtain remotely reliable coefficients for storage losses in different countries of the

EU (Pringle, 1996). Thus, the model works on the assumption that no storage losses occur, in the knowledge that this assumption is far from ideal. The alternative option to include an arbitrary storage loss coefficient was discarded because it would make validation of the model much more difficult. A country like Greece or Italy that does not record storage losses, would be severely affected by an arbitrary storage-loss factor, and unable to balance its recorded supply and demands.

Quality transfer

Initially it was thought a good idea to include quality transfer activities in the model, to represent the actual downgrading of seed and early potatoes into ware, starch or animal feed, and the down grading of ware potatoes into animal feed. Unfortunately, this idea had to be dropped, once it proved unrealistic to obtain any kind of reliable data for such activities, with no means of potentially validating the coefficients. Rather than using hypothetical data based on multiple assumptions, it was decided to exclude quality transfer activities all together from this model.

6.5 Main constraints

Supply

For each country the supply of potatoes (from potato producing activities) needs to be larger than, or equal to zero.

Balance

For each country and type of potato, the total supply and total demand of potatoes is to be equated. The excess supply of potatoes not needed by any of the recognized markets for human consumption, will be consumed by the activity C49, which represents animal feed and general losses. Implicitly the model assumes that the market losses will be the same for every year.

Consumption

In reality the consumption of potatoes is not completely fixed each year, but varies around an average consumption, and is dependent on both the price of potatoes and substitute goods. In the model, the consumption of potatoes is constrained at fixed levels of consumption per region as best reflecting the base year as possible.

Trade

The export of potatoes is unrestricted per country, assuming that every region would like to maximize its export potential once the domestic market is supplied. The imports of potatoes are limited to the maximum import level of potatoes for the base year, assuming that countries do not want to increase the import of potatoes.

Land

The major first constraint on the potato producing activities is the availability of land. The activities P11,P21 and P23 put a claim on the available land that is suitable for the production of high quality, certifiable seed tubers. Similarly, the activities P31, P33, P34 and P35 put a claim on the land that is suitable for the reproduction of early potatoes.

Each country is allocated its current (1991) area for the production of potatoes. If through the use of TPS technology a smaller area would suffice, than the excess land will be used for the production of P00 and generate an extra income. If for some reason, the current area does not suffice, than additional land can be taken into production. This will however attract a penalty cost for such additional land will not be able to generate other arable products. The cost of using an additional hectare of land is higher than the expected revenues from using one hectare less for the production of potatoes. This has been done to reflect the fact that in most countries it is much more difficult to find extra arable land than it is to cultivate a general crop on excess land.

6.6 Data, assumptions and software packages used

The data that were used for the construction of the model have been taken to apply to the 1991 production year. This is the most recent production year that showed reasonable balance between supply and demand (European Commission, 1992) and for which the statistics are reasonably complete for most of the EU countries. The idea of calculating the average data from three consecutive production years was contemplated but rejected. Averaging prices and trading volumes over a three-year period was not thought to improve the quality of the data, since the prices of shortage years have a direct effect on the prices of the following year. Instead the option was to limit the data collection to one calendar year.

Despite careful selection of the base year, the availability of reliable and consistent data for the EU potato industry proved to be scarce. In the case of Spain, for instance, the area used for certified seed production is only known by estimation and thought to be around 10,000 ha/year, with no data on the amount of seed being produced. This kind of data limitation greatly reduces the reliability of the final end use of the model. Because even when a reasonable estimate can be made for the amount of seed that will be produced with the use of TPS technology, the effect of the technology as compared to the current situation will be the result of two estimates.

Potato production data such as yields were taken from the leading sources of information for the EU, most notably the German ZMP (1992, 1995), the British PMB (1995,1996), the European Commission (1994, 1995, 1996) and the Dutch VBNA (1995). In most cases, only the average yield for a special type of potato production was known, which meant that the yields for potato production with/ with out the use certified of seed had to be estimated. For most cases, the yields with the use of certified seed were set to be either 5 or 10 % higher than the national average for that type of production. The yield with the use of home saved seed was subsequently calculated by means of the following formula:

$Yh = Ph / Ah = (Pt - Pc) / (At - Ac)$

with

Yh= yield from home saved seed

P= production, Y = yield, A = planted area

h = home saved, c = certified, t = total

With regards to the yields from seed tubers derived from TPS production (the activities P23, P33, P34, P43, P44, P53, P54) were all assumed to yield the same as their corresponding activities that use certified clonal seed.

Per country, the potato cultivation costs (without seed costs) were obtained from secondary data such as PepsiCo (1992) and European Commission (1994), and assumed to be equal for the activities P41 to P45. If no data was found for the cultivation costs of early and seed potatoes, than they were assumed to 50 % higher for early potatoes and 100 % higher for seed potatoes. This was done to reflect the higher cultivation costs involved with the production of the respective types of potatoes.

The sales price for ware and early potatoes was derived from EU retail statistics. The consumption prices for early and ware potatoes have been obtained, or derived from EU price statistics (European Commission, 1990a) The process paid by the processing industry are taken to be the same as the national average potato price paid to farmers in the relevant region (European Commission, 1994). The prices paid for use as starch and cattle feed are taken to be 70 % and 40 % of the ware potato producers price respectively. An overview of the available and deducted data that have been used in the construction of this model is presented in Appendix A.6.

The transport costs were calculated from the EU statistics on road transport (European Commission, 1990) and the distances by road between the centers of the countries involved. (See Appendix A.8) The transport costs to and from the Netherlands have been reduced by 10 % to reflect the fact that this country can benefit from economies of scale since it has a market share of 25 % in the EU road transport sector.

The frame work of the LP-matrix to simulate the EU potato industry has been presented earlier in Table 6.2. The actual dimensions of the matrix were as follows; 620 columns for the activities (157 production , 68 storage, 45 consumption, 350 trade) and 306 rows for the constraints (69 supply, 71 balance, 11 storage, 41 consumption, 79 trade, 35 land).It was constructed in four Excel. 4 spreadsheets, which were subsequently solved with the use of the LINDO software package.

6.7 Alternative uses for this model

With relative ease, this model structure can be modified and utilized for other types of assessment such as:

i The assessment of TPS technology using transplants. To assess this type of TPS technology the values that need to be changed are the yield and production costs in the first year (P13). Furthermore an extra claim will be placed on the available land, since transplants also occupy an area in the greenhouse for a few weeks.

ii The assessment of other technologies. By redefining activity P13 as the production of seed potatoes from aerial tubers (or micro-tubers) for example and adjusting the production costs and yield coefficients, the model can be used to assess the economic value of this type of potato propagation.

iii By enhancing the level of detail this model can be used to study the effect of TPS technology for a specific region of a country. Likewise the model can be expanded in its geographical area to include (potentially) new members of the EU.

The model can also be used to optimize the achievement of other goals such as the environmental impact of potato production. In this case the objective function will have to be rewritten in such a way that as the activities carry an environmental value.

It is also possible to use this model as a basis for a multiple goal programming approach of the impact of TPS technology.

7. VALIDATION AND SENSITIVITY

7.1 Introduction

The ultimate usefulness of the model that has been developed and described in the previous chapter, depends critically on the way in which the simulation of the EU potato industry corresponds with the reality of the industry.

This chapter will briefly review the theoretical background of model validation (7.2) after which options for validating the EU potato model will be discussed (7.3). Subsequently the sensitivity of the model will be analyzed in section 7.4. This than leads to the conclusion that the model is sufficiently suitable to generate an indication about the expected impact of TPS technology

7.2 Theories on model validation

Validation is an essential element in model development, to assure that results are perceived as credible and realistic by end users. This aim is frustrated by the fact that it is theoretically impossible to validate a model, for "Models can never be validated, only invalidated" (McCarl, 1984). It is possible to test the performance of the model for several uses, which will than lead to the conclusion that the model is either proven to be invalid, or not proven to be invalid. The not proven to be invalid will give an increased degree of confidence in the model for that specific use.

Unless the model is of very small dimensions, it is generally not possible to test it for all potential uses, and therefore it can only be ascribed a limited degree of confidence for a limited range of uses. The choices of how and for which purpose a model is tested can only made subjectively by the model builder, and thus it will never be possible to develop an objective and totally accepted approach to model validation (McCarl, 1984). Despite these fundamental limitations, the testing of a model is generally known as the validation process, and a model that has not been discredited by (one or more) tests, may be deemed to be valid for the purpose for which it has been tested.

The literature contains several excellent publications on the subject of model validation, most notably (McCarl, 1984, Norton et al. 1980; Hazell et al.1986; and Jakeman et al. 1993.)

McCarl (1984) distinguishes between two types of validation, namely technical validation and operational validation. Technical validation covers the testing of the internal consistency of the model, and whether or not it is reliable for a single and specified use. Operational validation covers the testing of the actual utilization of the model for practical purposes in different situations, and whether or not it performs properly in those circumstances.

Operational validation is the most difficult, since it requires the model to be used in several different situations which should be accompanied by a continuous model evaluation process. By using the model in different situations, the operational validation process can easily end up in a circular reasoning process: extrapolationary use of the model outside its original conditions, demands a very different type of validation, which can only be achieved by testing the model outside its original conditions (Jakeman, 1993). A further problem that frequently arises in achieving operational validation is the inability to validate future events until they actually happen, if they happen at all. An excellent model to simulate the long-term effect of ozone depletion on wheat growth can for example be modified and utilized for different regions and different crops. But the ultimate operational validation of the model can not take place until the ozone depletion actually occurs, which may (and hopefully never will) occur.

In the case of the model for the EU potato industry, operational validity could not be achieved in the short term. First, it would have to be used in a number of different situations, such as the assessment of a different new type of technology, the assessment for a modified geographical area (either smaller or larger) or the assessment for a different time period (e.g. an average year during the 1980s or late

1990s). For this reason the remainder of this chapter will concentrate on the technical validation process.

Validation can be done for either the complete model, or only a part of it. Norton et al (1980) remarked that validation is most important for those parts of the model that are closely related with the modeling objectives. Whether or not a model is very reliable on its prediction of a minor activity may not hinder its reliability for its intended overall use. In the case of the EU potato model, it would be less important to validate the simulation of the Luxembourg potato industry, since it is generally included with the statistics of the Belgian industry.

McCarl (1984) states that validation of a model (both technical and operational) can be done by assumption, by results or by a combination of the two. Validation by assumption encompasses one or more of the following five testing procedures; testing the model against expert opinion, testing the model against previously recorded uses, testing the model against the theory of the simulated system, testing the model against data from which it has been built, and testing against the logical structure of the model. (McCarl, 1984). Validation by assumption is almost always done implicitly in the model building and debugging process and may sometimes be termed model verification.

Validation by results is based on the comparison between modeling results and the observed and measured reality of a system. Hazell et al (1986) mention the following three sources of error that may result in model inconsistencies, which in turn hinder the validation process of economic models: (1) errors in the calculation of the marginal costs of production, (2) errors in the reported price, (3) errors in the reported quantities of produced and sold goods.

Validation by results should consist of the following four steps (McCarl, 1984);

1 Assemblance of a parameter-outcome set and comparison with the modeling results. For this step it is obviously essential to use a data set that has not been used

previously in the construction process of the model. Unfortunately "in many countries, data corresponding to some of the model's variables simply do not exist"(Hazell et. al, 1986). Thus placing a limitation on the ability to make the required comparison.

2 Conceptualization of specific validation tests. Several statistical tests can be applied on the differences between the observed and expected results (Dent et al, 1979). Hazell et al (1986) mention the following six tests in particular with reference to the validation process of sector (or industry) mathematical programming models: the capacity test, the marginal cost test, the land rental test, tests on the levels of input use, production tests and price tests. Other types of test are those for plausibility, possibility, supply function , predictive change and predictive tracking (McCarl, 1984). For this step, again, it holds true, that it is significantly easier to identify a suitable statistical test, than to obtain the necessary and objective data.

3 Measurement of the degree of association and the definition of the rejection/ acceptance criteria. Jakeman (1993) described the aim of this step as being to achieve a situation whereby residual errors of mismatch conform to the following criteria;
(i) their mean value should be zero, and their standard deviation as small as possible
(ii) they should be significantly correlated with themselves in time; and
(iii) they should not be significantly correlated with any of the observed input sequences (Jakeman et al, 1993 p. 28)

4 Deciding what can and should be done with models that have failed one or more validation tests. Four options are open once a model has failed a validation test: (i) the model can be discarded, (ii) the validation test may me judged improper and discarded, (iii) the model may be judged valid for a limited range of uses (iv) the model may be modified (McCarl, 1984).

In conclusion it is important to note that models that prove to be incorrect predictors of specific numerical values may still be considered as valid and useful if they predict the right direction and magnitude of change (McCarl, 1984)

7.3 Validating the EU potato model

The model for the EU potato industry is actually a composition of two separate simulation activities. On the one hand, the model attempts to simulate the working of the industry in an average year, without the use of TPS technology. On the other hand, the model simulates the (expected) performance of potato production with TPS technology, in anticipation of it being allowed into the EU. This distinction between these two simulation activities is highly significant for the validation procedure. If the model is valid in respect to the simulation of the current situation, but not in respect to the performance of TPS, then the assessment of the new technology becomes impossible. The same holds true for the situation whereby the simulation of the TPS performance is deemed valid, but the representation of the EU potato industry does not resemble reality. This section will first discuss the options of validating the simulation of the current situation, and subsequently of validating the TPS performance.

<u>The EU industry, without TPS</u>

Under the constraint that the use of TPS is excluded for the whole of the EU, the model should replicate the actual situation of the 1991 production and consumption year. Assuming that access to all the relevant data of the performance of the industry for 1991 are available, then it is still likely that the simulated optimum situation will differ somewhat from the actually observed situation for that year.

It is accepted that most of the participants in the industry will aspire to achieve the optimum situation (for themselves) but that this is not always achieved. This is definitely the case with the expensive production of high quality seed potatoes in the Netherlands, that end up as cattle feed under the STOPA arrangements. STOPA pays a minimum price to seed potato growers who were unable to seed all of their produce. On average STOPA bought 65,000 t of seed over the years 1989-1993, (This is the equivalent to the output of more than 2000 ha of land, and some 2% of the EU seed area) . The STOPA is an insurance system run by the seed potato sector, to buy up those seed potatoes that can not be sold for a (previously agreed) minimum price. Thus establishing a bottom-price in the market, which protects the producers' margin. Since the STOPA losses are paid for by the producers collectively, the aim is always to avoid any excess seed potatoes on the market. A standard optimizing routine would eliminate the production of seed potatoes for the end purpose of cattle feed, and allocate the resources to other forms of production. Thus, the conclusion is reached that a profit maximizing model can only represent reality, if the reality is already close to an optimal situation. That this is not the case for the EU potato industry, is demonstrated by the example of the STOPA-activity. The model does not react to the uncertainty in the industry (e.g. yield variation) while real world decision makers do. The model assumes knowledge of all relevant data for the season.

In the construction process of the model, all the relevant and available data for the EU potato industry over 1991 have been used. Although various sources of statistical secondary information are available (ZMP, PMB, EU, VBNA, FAO) many of them use each others data in the compilation of their own statistics. A German estimate of the French starch area doesn't become more valid because it is taken over by the British and EU counterparts. It really is therefore impossible to obtain a "new" independent data set for the year 1991 for validation, that has not been used in model construction before. Thus it will not be possible to validate the model by results, and it will have to be achieved by construct or assumption.

From the five procedures of testing a model by assumption (McCarl, 1984) not all may be applied to this model. Testing the model against its previous use (antecedent validity) was impossible since the model is wholly novel and is in use for the first time. In the absence of any formalized theory of how the EU potato industry functions, or should function, the testing of the model against such a theory is not possible either.

The testing of the logical structure was carried out in the "debugging" process to the extent that previous errors in the model, whereby for example potatoes could be produced without the use of land, or consumed without being produced, have been duly rectified. The model is also consistent in the dimensions of all of the four area's that are required by Hazell et al 1986; (product-product, product-input, product-price, technological coefficients). All activities and constraints are described by the same dimensions (1000 ha, 1000 ECU's and 1000 t).

Testing the model against expert opinion was done by discussing the assumptions and results of the model with several potato specialists, and consulting several national manuals of potato production, which were seen as another form of expert knowledge. The experts agreed that even to themselves it is difficult to obtain a clear picture of what is (or has been) happening in the EU potato industry. By far the largest gathering of potato experts that took place during the study period was the 13th triennial meeting of the European Association for Potato Research in 1996. It was found that most of these researchers pay very little attention to economic side of potato production. Experts from the potato trade, who are definitely more aware of the economic side of the industry, were approached at the second and third World potato congresses in the UK and South Africa respectively. On both occasions it was found that these commercial experts do not have a great desire to share their knowledge.

Testing against the expert-knowledge as documented in some of the national agricultural handbooks, did not prove to be conclusive in the case of the Dutch starch sector. The 1991 publication by the Dutch PAGV-specialists reports that the "average" starch yield lies at 45 t/ha, which by multiplication of the starch area for 1991 would lead to a total production of at least 2,539,350 t (62,700 ha * 45 t/ha = 2,821,500 t., minus 10 % used for seed). The specialist from the VBNA however reported a total starch production of 2,106,312 t over the same area, which brings the average yield to barely 34 t/ha. Such observations raise doubts whether an expert range of more than 10 t/ha in itself can be considered as acceptable. From consultation process potato experts and expert-literature, no significant reasons where found to reject the model as being broadly representative.

Testing against the original data

Naturally, the model could be tested against the data from which it was constructed. Before this the validity of these data has to be accepted and should be questioned on many occasions. For instance on the trade statistics the official Dutch sources (CBS 1992) reported an export of 1,000 t of seed potatoes to the state of Vatican City, which has a total (mostly non-arable) area, of only 44 ha. Obviously these seed potatoes could not have been planted at a rate of more than 22 t/ha in the Vatican. Either they have been re-exported to another country (most likely Italy), or they have been used as ware potatoes (which would bring the average consumption close to 1000 kg/head). In this situation, the non-validity of the statistics is easily spotted, and could be rectified with additional research. In most other cases, such invalid statistics are much more difficult to discern. Therefore, it was not without reason that McKerron remarked "*Scientists and officials examining statistics must not discount the possibility of downright dishonesty at the source of some of the figures* "(McKerron, 1992 p.72).

When the observed model output (in the situation of no TPS use) is tested against the expected out put, on the basis of the original data set, Table 7.1. emerges

Table 7.1 Comparison of expected and observed results ('000 ha).

	Area	P11+P21 seed	P30 earlies	P31	P35	P40 ware	P41	P45	P50 starch	P51	P55
Germany											
Exp.	342	25.19	25.00			222.00			70.00		
Obs.	342	25.19	25.00	25.00	0.00	220.80	133.14	87.66	71.00	62.00	9.00
Diff.	-0.0%	0.0%	0.0%			-0.5%			1.4%		
France											
Exp.	171	13.94	24.00			98.00			34.30		
Obs.	171	12.94	23.91	23.91	0.00	100.01	100.01	0.00	34.14	34.14	0.00
Diff.	0.0%	-7.2%	-0.4%			2.1%			-0.5%		
Italy											
Exp.	118	2.12	30.00			86.00					
Obs.	118	2.12	29.69	0.00	29.69	86.20	55.13	31.07			
Diff.	-0.0%	0.0%	-1.0%			0.2%					
Netherlands											
Exp.	180	37.17				80.00			63.00		
Obs.	180	35.46				80.54	80.54	0.00	64.00	22.14	41.86
Diff.	-0.0%	-4.6%				0.7%			1.6%		
Denmark											
Exp.	43	7.70				12.00			23.00		
Obs.	43	5.26				14.76	14.76	0.00	23.00	23.00	0.00
Diff.	0.7%	-31.7%				23.0%			-0.0%		
Bel-Lux											
Exp.	58	1.54	8.00			48.00					
Obs.	58	1.54	8.00	8.00		48.46	48.46				
Diff.	0.8%	0.0%	0.0%			1.0%					
UK											
Exp.	176	19.67	16.00			140.00					
Obs.	176	19.66	16.00	6.19	9.81	140.33	140.33	0.00			
Diff.	0.2%	-0.0%	-0.0%			0.2%					

Table 7.1 Comparison of expected and observed results (000 ha).

	Area	P11+P21 seed	P30 earlies	P31	P35	P40 ware	P41	P45	P50 starch	P51	P55
Ireland											
Exp.	20	2.64	3.00			14.00					
Obs.	20	2.64	2.42	0.14	2.28	14.94	14.94	0.00			
Diff.	1.8%	0.0%	-19.5%			6.7%					
Spain											
Exp.	266	10.00	43.00			213.00					
Obs.	266	10.00	43.00	0.00	43.00	213.00	118.31	94.69			
Diff.	-0.0%	0.0%	0.0%			-0.0%					
Portugal											
Exp.	109	0.40	17.00			92.00					
Obs.	109	0.40	17.00	17.00	0.00	91.60	26.61	64.99			
Diff.	-0.4%	0.0%	0.0%			-0.4%					
Greece											
Exp.	52	0.44	14.00			38.00					
Obs.	52	0.44	14.00	14.00	0.00	37.56	1.25	36.31			
Diff.	-0.8%	0.0%	0.0%			-1.1%					
EU-12											
Exp.	1535	120.81	180.00			1043.00			190.30		
Obs.	1535	115.64	179.02	94.24	84.78	1048.21	733.49	314.72	192.14	141.28	50.86
Diff (%)	**0.0%**	**-4.3%**	**-0.5%**			**0.5%**			**1.0%**		
Diff (ha)	**138**	**-5,162**	**-984**			**5,207**			**1,836**		
Trade	Exports	to non EU	(1000 t)		Imports from non EU (1000 t)						
EU-12	seed	earlies	ware		seed	earlies	ware				
Exp.	250	0.00	200.00		0.00	450.00	0.00				
Obs.	150	0.00	0.00		0.00	450.00	0.00				
Diff.	100	0	200		0	0	0				

Table 7.1 shows that the percentile differences between the expected and observed production areas for the whole of the EU lie below 5 %. The largest differences are observed in the total seed production area (- 4.3 %). Although this difference is ideally not desired, neither is it a cause for great concern. It indicates that, according to the model, the EU could meet its needs for certified potatoes on a production area that is 4.3 % smaller than actually observed.

This difference is likely to become a lot smaller if the model were adjusted to include the losses that occur during storage and transportation. Other causes for the differences may lie in too optimistic assumptions about the yields of seed potatoes, and/or to low assumptions about the planting rates for potato production. A further potential cause lies in the fact that the export of seed potatoes to countries outside the EU is 100,000 t lower than expected, thus requiring a smaller area of seed potato production in the EU. The additional area in practice may simply be a some safeguard against risk.

The countries that show the largest deviation in seed production area are France (-7.2 %) , The Netherlands (- 4.6 %) and Denmark (- 31.7 %). All these countries also show a larger than expected ware production area. Since the model does not take account of the trading margins of the merchants, it is likely to under represent the total costs of transport between countries. Thus the option of buying ware directly, rather than seed becomes more attractive to countries that show low average yields. (Spain, Portugal,).

The deviations in early potato production areas are less than 2 percent for all countries, with the exemption of Ireland. The smaller area of early potatoes for Ireland can be attributed to the comparative advantage of this country in producing ware over early potatoes. In a situation of low transport costs, the country would naturally specialize in the production of ware potatoes, and import early potatoes.

The deviations in trade activities between observed and expected values are much more difficult to discern. When the real situation is such that ware potatoes are exported from Belgium into Holland, and than re-exported into Germany, the model will only provide the activity of export from Belgium to Germany. Furthermore, if the real situation is such that 100 t of ware potatoes from Belgium are exported into Northern France, and 80 t of ware potatoes from Southern France into Italy, the model will only provide the concluding activity of 20 t from Belgium into Italy. Validating the trade activities is furthermore hindered by the paucity of reliable secondary data on this activity.

The model under-represents the export of seed and ware potatoes from the EU as a whole, but appears correct with respect to the import of all types of potatoes and the export of early potatoes. The under-representation of exports is most likely due to the fact that in the model the exclusion of merchant margins makes it more profitable to supply ware and seed potatoes to the south of the EU than to countries outside the EU.

The optimal value of a model that incorporates all the production and handling costs of the industry as well as all the different forms of revenues of the potato industry, should be around zero. If the optimum value was significantly below zero, the running of the industry as a whole would be a loss making activity. If the optimum value was significantly above zero, some party in the would be making unjustified profit margins, which in a competitive market would not be sustainable for very long.

The optimal solution of this LP model has a total net financial value of 10.6 billion ECU, which is significantly above zero. The reason for this high value is due to fact that the model does not incorporate all the handling costs and transportation costs within countries. In 1991 the farm gate value of the EU potato crop lay at more than 5.1 billion ECU (European Commission, 1995). So, according to this model the retail value of the potato crop was (5.1 + 10.6) 15.7 billion ECU, or three times the producers price. EU data for 1988 indicate that the difference between producers price and retail price varied between 95% [1] and 762 % (European Commission 1996, European Commission 1990).

The obvious question arises as to why these margins have not been simulated into the model, to achieve an optimum solution that is closer to the expected zero. The reasons for are twofold: firstly it would require a very large and separate study to obtain any form of reliable data about the handling margins in all of the different countries and regions of the EU. Secondly, the fact whether merchants are handling ware potatoes grown with or without TPS technology, will not have any impact on their cost structure, and therefore their gross margins are unlikely to change. Thus it may be assumed that the lack of precise knowledge about the handling margins has an equal effect on the optimal situations with or without TPS technology

The model does not give an exact representation of the reported reality in 1991, which may also be due to the fact that the reality was not an optimal solution for the whole of the EU industry, or that the picture of reality available in the official statistics is unreliable.

b Validation of the TPS-assumptions

The simulation of the potato production with the use of TPS technology could not be tested against results, since there were no results available for the EU. However, as described in Chapter four, a TPS field-testing project for the UK has been initiated. Once these data become available (1998) the assumed performance of TPS-varieties in the UK can be tested against the realized performance at trial fields. Thus, the validation of the TPS-performance also had to be completed by assumption.

[1] The 95 % difference illustrates the impossible result of comparing two different sources of EU statistics. In 1988, according to the EU the Spanish producer price was 147.5 ECU whilst the consumer only paid 140 ECU. Thus we are led to believe that the consumption of potatoes is a subsidized activity in Spain.

Because experience with commercial TPS in industrialized countries is still very limited, it proved difficult to obtain significantly robust data or experts who were sufficiently knowledgeable. Since all the available data from the USA (both published and expert) has been used in the construction of the model, no new information could be expected from this source. A potential source of reference proved to be South Africa, where commercial use of TPS technology started in 1994 (Merwe et al, 1997). In South Africa, the TPS was direct seeded under irrigated pivots, and yielded between 11 and 19 t/ha. The low yields was attributed mainly to incorrect production techniques since the growers were new to this form of technology (Merwe et al, 1997). With experience better results are expected to be achieved.

As a consequence of this limited availability of data and other information about the performance of TPS technology it was not feasible to subject the TPS-simulation part of the model to any rigorous form of testing or validation.

7.4 Sensitivity analysis

Sensitivity analysis is concerned with the way in which changes in the value of a selected key parameter affects the optimal solution of an LP model (Winston, 1995). It is though most important to see for which parameters a relative small change in the value leads to a relatively large change in either the value of the optimal solution or the composition of the optimal solution.

The model has been run many times, with slightly changed parameters and during that process the following observations were made.

Yield: As expected, the model is sensitive to the yields for the potato producing activities. For instance a small increase of only 5 % in all the yields in Spain (which has 17% of the EU potato area) will lead to a markedly different optimal solution; First of all the optimal solution improves by 103.7 million ECU, the import of seed potatoes into Spain increases from 48,195 t to 60,000 t per year, whilst the import of ware potatoes falls from 354,000 t to 116,000 t. This extra production capacity in Spain enables the EU as a whole to increase the export of ware potatoes to non EU countries to 200,000 t, and increase the export of seed potatoes with 75,000 t per year. In the opposite situation where yields across Spain decrease by 5 %, the optimal solution decreases by 270 million ECU, and there is a need for the EU as a whole to import more than 280,000 t of ware potatoes.

Similar sensitivities were found for the yields in other countries in the EU, with effects that were related to the total size of the potato producing area. Furthermore the model was found to be sensitive to the values of the seed rates that are being used. Slight increases in the seed rate have an immediately noticeable effect on the optimal solution.

Beside the yield and seed rates, the model has also been tested for changes on the demand side, the availability of land and the maxima for imports of seed potatoes. As expected, the model also proved sensitive to such change. Limited availability about the actual demand for various types of potatoes, as well as the imports of potatoes, meant that this sensitivity of the model had to be recognized, without the opportunity of rectifying any potentially inaccurate data.

7.5 Conclusion

A significant shortage of available and reliable data on the functioning of the EU Potato Industry hampers validation of the LP-model of the industry. The model that has been build for this study appears to give a realistic - although not a very detailed- simulation of the industry, and seems able to reflect adequately the impact of changes of the parameters on the optimal solution. In the absence of any other type of model that represents the whole of the EU potato industry, this model can be used to obtain an indication of the size and direction of changes that is likely to result from the arrival of a new form of technology. According to McCarl (1984) such a model can be deemed valid for its intended purpose.

8. RESULTS

8.1 Introduction

This chapter presents and discusses the implications of a number of different scenarios for the uptake of TPS technology. By changing some of the parameters, the mathematical model of the EU potato industry can be used to simulate specific scenarios for the uptake the technology. The number of different scenarios explored is a subset of a large potential number; these have been selected purposely to examine specific circumstances.

The most obvious scenario to explore concerns the impact should the technology perform similarly to the way it does in the USA. This involves a purchase price for TPS of 2,450 ECU/kg, a planting rate of 200 g/ha (as described by Renia, 1995), cultivation costs[1] of about 4,800 ECU/ha and a seed tuber yield[2] of 18 t/ha, and the yields of subsequent ware crops from such seed tubers that are equal[3] to those of other commercially available varieties.

The economic outcome for the EU potato industry improves, when TPS becomes available under the above conditions. The difference between the optimum solution without TPS and the optimum solution with TPS will be defined as the Improved Gross Margin (IGM) for the EU potato industry. The IGM reflects the total economic value of the improved allocation of resources that are needed for the functioning of the EU potato industry, and that are solely attributable to the uptake of TPS technology. The IGM does not include the capital costs.

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[1] ESCA-genetics used an internal guideline of $ 6,000 cultivation cost per ha; Chadwick (1996) mentions the following cultivation cost (without seed) in the UK for lettuce (£ 5176) carrots (£ 3417) cabbage (£ 2504,-) and Brussels sprouts (£ 1479);.PAGV (1994) mentions the following costs for the cultivation (without seed) of lettuce (dfl 9086), red cabbage (dfl 7158) Brussels sprouts (dfl 4375) in the Netherlands.

[2](Hest, 1996),

[3] As indicated by (Love, 1996)

Thus the IGM identifies where the maximum achievable limits of the improvements lie. Whether or not these limits are achievable in practice will depend on many other factors such as market imperfections that might restrict the entrance of improved technologies to some areas. How the benefits of the IGM will be split between the producers, merchants and consumers can not be derived from this model. In a perfectly competitive market, with numerous suppliers and consumers, the IGM would be transferred completely to lower the market price of ware and early potatoes. Whether the EU potato markets fully adhere to this description is debatable, and therefore it would be unwise to predict how the IGM would be divided between the stakeholders of the industry.

In this chapter the following types of uptake scenarios will be investigated;
- The influence of the TPS price on uptake of TPS-technology (8.2).
- The influence of the TPS cultivation cost, whereby clonal seed tubers are produced from true seed (8.3).
- The effect of the seed tuber yields from the direct seeding of TPS (8.4).
- The effects of limited consumer acceptance for TPS varieties (8.5).
- The impact of TPS technology when its use is limited to only the four southernmost members of the EU (8.6).
- The impact of TPS technology when its varieties would only be deemed suitable for the production of starch potatoes (8.7).

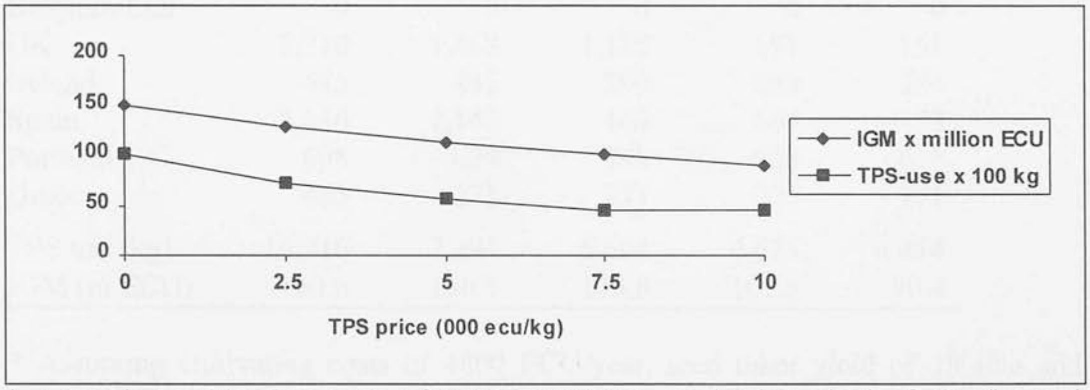
Finally the last section (8.8) gives a summery of the outcomes of the different scenarios, and discusses their implications.

8.2 The influence of the botanical seed price

The price at which botanical potato seed becomes available to the EU growers seems to be one of the parameters for which closer observation is desired. The EU potato model has been run with a great number of different price levels for botanical seed. As expected, the attractiveness of the technology for the EU potato industry will decrease when the price of the botanical seed increases. The effect of five price scenarios ranging from zero to 10,000 ECU/kg are now examined in more detail. The price of 0 ECU/kg is a baseline scenario. If the technology is not attractive when the seed is provided free, it will be impossible for the technology to succeed without subsidy. The price of 2460 ECU/kg represents the current world market price for American TPS varieties, when imported from Chile. It is assumed that EU legislation could be changed to allow the import of TPS from Chile at this price.

A price of 5,000 ECU/kg represents the cost of producing botanical seed in a low wage country of the EU, should the import of TPS be banned. According to (Kalazich, 1996) some 80 % of the production costs of TPS in Chile can be attributed to the labor costs of seasonal workers needed for pollination. The remaining 20 % is for laboratory equipment and highly skilled supervision. Since the wage level of unskilled laborers in Portugal is about twice that of Chile it has been estimated that the production cost of TPS in Portugal would also be twice those of Chile. Model runs at price levels of 7500 ECU/kg and 10,000 ECU/kg were made to investigate the prospect of substantially higher prices for botanical seed. The actual price of botanical seed could be higher, if the breeder needs to receive royalty payments to recoup previous investments. The effect of increasing prices for botanical seed from 0 to 10,000 ECU/kg. is presented in Figure. 8.1.

Fig. 8.1 IGM and TPS use at different price levels for TPS*.



* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The first conclusion that follows from Figure. 8.1 is that the use of TPS technology will lead to a significant improvement of the IGM for the EU potato industry. Under the scenario whereby the import ban is lifted, and TPS becomes available at world market prices, the IGM is expected to be 130 million ECU per year. In the scenario whereby TPS becomes available at four times the world market price, the IGM could be still 90.4 million ECU. The modeling results on which Table 8.1, as well as all the other Tables in this section are based, are included in Appendix A9.

Since it is likely that an uptake of TPS technology would not be limited to only the EU, it has to be assumed that several non EU-countries will also switch to this technology. Therefore the demand for seed potatoes outside the EU is likely to fall substantially. The effect of such decreasing market is incorporated by limiting the maximum allowable export of seed potato tubers from the EU from 250,000 t/year to 100,000 t/year.

Table 8.1 TPS use (kg) by country at different price levels.

	TPS-price (ECU/kg)				
Country	**0**	**2,460**	**5,000**	**7,500**	**10,000**
Germany	1,487	1,487	1,487	1,487	1,487
France	325	0	0	0	0
Italy	1,689	1,718	1,437	1,437	1,437
Netherlands	0	62	62	33	33
Denmark	451	0	0	0	0
Belgium/Lux	0	0	0	0	0
UK	2,210	1,462	1,185	151	151
Ireland	445	445	299	284	284
Spain	2,446	1,147	164	164	53
Portugal	698	698	698	698	698
Greece	465	271	271	271	271
TPS use (kg)	10,216	7,291	5,604	4,525	4,414
IGM (m ECU)	150.6	130.5	113.8	101.5	90.4

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The uptake of TPS technology would take place in most of the countries of the EU, as can be seen from Tables 8.1 and 8.2. Germany, Italy, the UK and Spain would be the largest users. For a country like Belgium, with a very low cost structure for the production of ware potatoes, it would be more beneficial to concentrate on the ware production activity, and import all of its seed potato tubers from neighboring countries.

The use of TPS technology allows significant increases in the production areas of certified seed tubers, which was previously identified (Chapter 7) as one of the stringent limitations for the EU potato industry. Italy, Spain, Portugal and Greece are the countries for which the increase in seed potato area would be the most dramatic. Interestingly Germany also opts for a substantial increase in the seed potato area through the use of TPS technology. This trend can be explained by the fact that a larger certified seed area allows Germany to produce a greater percentage of its ware potatoes with certified seed, which in turn leads to higher yields per hectare. Apart from Belgium and Denmark, for which ware production is comparatively more profitable, few countries show a significant reduction in certified seed potato area. Again this can be explained by the tendency of countries to use more certified seed and increase the average yield of ware, early and starch potatoes.

Table 8.2 Production area (ha) used for certified seed potatoes at different TPS prices

	TPS price (ECU/ kg)					
Country	**0**	**2,460**	**5,000**	**7,500**	**10,000**	**no TPS**
Germany	32,629	32,629	32,629	32,629	32,629	25,194
France	13,849	12,381	12,381	12,381	12,381	12,935
Italy	8,445	8,589	7,184	7,184	7,184	2,117
Netherlands	29,162	33,025	35,337	35,337	35,337	35,457
Denmark	2,253	1,795	1,795	1,795	1,795	5,258
Belgium/Lux	0	0	0	0	0	1,543
UK	11,780	15,251	16,778	20,420	20,420	19,666
Ireland	2,227	2,227	1,844	1,806	1,806	2,641
Spain	12,229	15,737	10,822	10,822	10,267	10,000
Portugal	3,489	3,489	3,489	3,489	3,489	403
Greece	2,326	1,357	1,357	1,357	1,357	435
EU-12	118,389	126,480	123,616	127,220	126,665	115,649

*Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

According to the model output, as presented in Table 8.3 and 8.4., the effect of TPS-use on the intra-EU trade of seed tuber potatoes is very limited. The reason for this is that the import constraints for the individual countries have remained unchanged. It is perceivable that seed tuber importing countries would lower their import quotas after the establishment of TPS technology, in order to protect their domestic seed industry. Under the EU regulations that protect the free movements of goods throughout the union, such import restrictions would not be allowed. However, less visible, but still highly effective import barriers could be constructed. Since most countries currently use their (modeled) import quota up to the maximum, such reductions would lower the IGM.

The model can easily accommodate potential reductions of seed tuber imports by individual countries. However, in the absence of any reliable estimates for the size of these reductions, they have not been included in this chapter. As reported in Chapter 2 it is difficult to obtain a true and accurate picture of the existing intra EU trade in seed potatoes. So it is equally difficult to defend any substantial changes to the current limits used in the model, (based on data provided by the ZMP).

Table 8.3 Seed tuber imports (t) at different TPS price levels.

	TPS price (ECU/kg)					
Country	**0**	**2,460**	**5,000**	**7,500**	**10,000**	**no TPS use**
Germany	85,000	85,000	85,000	85,000	85,000	85,000
France	85,000	85,000	85,000	85,000	85,000	85,000
Italy	33,700	70,991	120,000	120,000	120,000	120,000
Netherlands	2,662	0	0	2,682	2,682	0
Denmark	1,000	1,000	1,000	1,000	1,000	1,000
Belgium/Lux	70,760	70,760	70,760	70,760	70,760	34,916
UK	40,000	40,000	40,000	40,000	40,000	40,000
Ireland	0	10,000	10,000	10,000	10,000	10,000
Spain	60,000	60,000	60,000	60,000	60,000	60,000
Portugal	60,000	60,000	60,000	60,000	60,000	59,420
Greece	0	30,000	30,000	30,000	30,000	28,995
non EU-12	100,000	100,000	100,000	100,000	100,000	150,000
EU-12	539,122	612,751	661,760	664,442	664,442	674,331

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.4 Seed tuber exports (t) at different TPS price levels.

	TPS price (ECU/kg)					
Country	**0**	**2460**	**5,000**	**7,500**	**10,000**	**no TPS use**
Germany	0	0	0	0	0	0
France	29,230	0	0	0	0	11,805
Netherlands	495,460	594,907	657,711	661,751	661,751	664,110
Denmark	0	0	0	0	0	0
UK	0	0	0	0	0	0
Ireland	13,432	17,844	4,048	2,681	2,681	0
EU-12	538,122	612,751	661,759	664,432	664,432	675,915

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The use of TPS also has a noticeable influence on the areas that are being used for the production of ware potatoes. The increased provision of certified seed tubers, reduces the need for (lower yielding) home-saved seed. As a consequence, the average yields in the EU will rise. Since the total demand for potatoes is relatively stable (as is the EU population), a smaller area for ware production will suffice. Table 8.5 presents the projected ware potato areas throughout the Union, as well as the area that will be released for other agricultural uses. The reduction of the total potato area does not always mirror the changes of the botanical seed price to the full. The reduction at the level of 10,000 ECU/kg is larger than that at the lower level of 7500 ECU/kg. This is due to the fact that the reductions take place in different countries, and each country has a different alternative revenue for the extra available land. At a seed price of 7500 ECU/kg it is relatively more beneficial for countries like Italy and Spain to increase the ware area and decrease the ware imports, as opposed to the situation at other price levels.

Table 8.5 Ware potato production area ('000 ha) at different TPS price levels.

	TPS price(ECU/kg)					
Country	**0**	**2460**	**5,000**	**7,500**	**10,000**	**No TPS use**
Germany	215.1	215.1	215.1	215.1	215.1	220.8
France	99.0	100.5	100.5	100.5	100.5	100.0
Italy	71.3	73.1	75.3	75.3	75.3	86.2
Netherlands	80.6	80.7	80.7	80.7	80.7	80.5
Denmark	17.8	18.2	18.2	18.2	18.2	14.8
Belgium/Lux	50.0	50.0	50.0	50.0	50.0	48.5
UK	148.2	144.7	143.2	139.6	139.6	140.3
Ireland	14.8	14.8	15.2	15.2	15.2	14.9
Spain	187.3	187.3	199.5	207.7	209.1	213.0
Portugal	66.5	66.5	66.5	66.5	66.5	91.6
Greece	13.9	15.3	15.3	15.3	15.3	37.6
EU-12	964.5	966.2	979.5	984.1	985.5	1,048.2
reduction of potato area	73.3	71.9	61.5	31.9	52.5	0

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.6 clearly indicates the reduction of home-saved seed tubers after the introduction of TPS technology. Similar reductions are predicted for the production of early and starch potatoes. The fact that a reduction takes place had been expected. The exact extent of the reduction can not be predicted with much certainty. In the construction of the model best-estimates where used for both the percentage of home-saved seed as well as the yield from home-saved seed. Unfortunately, these estimates could not be verified to any reliable extent. The model however does indicate a trend of falling dependency on home-saved seed. Such a trend is beneficial for agriculture in general, since home-saved seed usually generates lower yields, and requires more pesticides than certified seed.

Table 8.6 The use (%) of home-saved seed tubers at different TPS price levels.

	TPS Price (ECU/ha)					
Country	**0**	**2,2460**	**5,000**	**7,500**	**10,000**	**no TPS use**
Germany	0	0	0	0	0	39
France	0	0	0	0	0	0
Italy	0	0	0	0	0	36
Netherlands	0	0	0	0	0	0
Denmark	0	0	0	0	0	0
Belgium/Lux	0	0	0	0	0	0
UK	0	0	0	0	0	0
Ireland	0	0	0	0	0	0
Spain	0	0	36	38	42	44
Portugal	0	0	0	0	0	71
Greece	0	0	0	0	0	96
EU-12	0	0	7	8	9	27

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Tables 8.7. and 8.8. indicate that the model predicts few changes in the ware potato trade, (in comparison to the situation without the use of TPS technology). Most ware importing countries continue to import the (modeled) maximum of ware potatoes. This reaction is logical since the ware exporting countries have the lowest production costs per tonne. The use of TPS lowers the total ware production costs for all countries, but the comparative differences in yield will remain. The most significant increase is that in the export of ware potatoes to non EU-countries. In the basic solution (without the use of TPS) the export quotum of 200,000 t was not being used completely, where as it is in all other situations where TPS is being used.

The reliability of the ware trade data without TPS is also questionable. Therefore the predicted results of trade flows after the introduction of TPS must be interpreted with care.

Table 8.7 Exports of ware potato ('000t) at different TPS price levels

	TPS price (ECU/kg)					
Country	0	2, 460	5,000	7,500	10,000	no TPS use
Germany	1,303	1,297	1,297	1,303	1,303	851
France	211	264	264	264	264	245
Italy	0	0	0	0	0	0
Netherlands	1,298	1,298	1,298	12,98	1,298	1,292
Denmark	279	300	300	300	300	144
Belgium/Lux	850	850	854	1,150	850	792
UK	500	358	296	147	148	149
Ireland	0	0	0	0	0	0
Spain	0	0	0	0	0	0
Portugal	0	0	0	0	0	0
Greece	0	0	0	0	0	120
EU-12	4,441	4,367	4,309	4,462	4,163	3,593

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.8 Imports of ware potatoes ('000 t) at different TPS price levels .

	TPS price (ECU/kg)					
Country	**0**	**2,460**	**5,000**	**7,500**	**10,000**	**no TPS use**
Germany	1,298	1,298	1,298	1,298	1,298	1,291
France	822	822	822	822	822	820
Italy	886	849	800	800	800	800
Netherlands	0	0	0	0	0	0
Denmark	0	0	0	0	0	0
Belgium/Lux	0	0	5	300	0	0
UK	0	0	0	0	0	0
Ireland	105	105	92	91	91	108
Spain	560	560	560	413	413	355
Portugal	320	320	320	320	320	185
Greece	244	214	214	214	214	0
Non-EU	200	200	200	200	200	34
EU-12	4,435	4,368	4,311	4,458	4,158	3,593

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The use of TPS would have a knock-on effect on the production of early potatoes. As for the ware potatoes, the use of home-saved seed is reduced substantially, and the average yield would increase as a consequence. The EU imports of early potatoes would decrease only slightly, since it is relatively more attractive to import them, from non-EU countries.

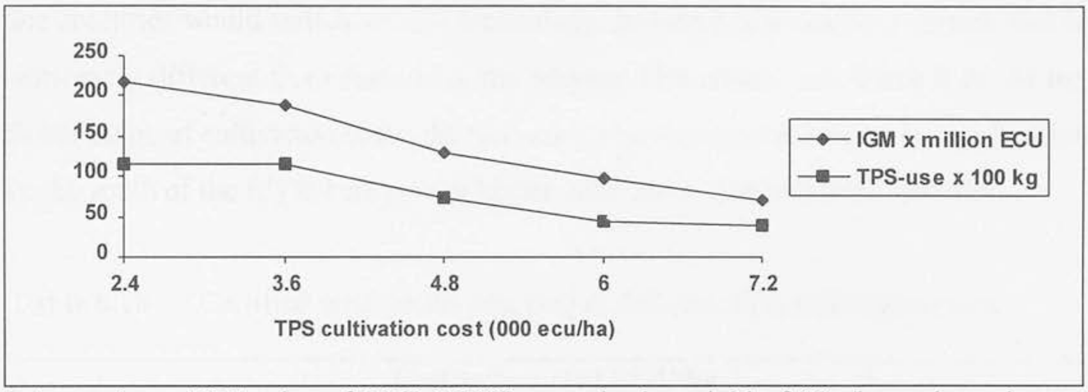
The effect of TPS use on the area used for starch production is limited, since the four starch producing countries already use a high proportion of certified seed without the use of TPS. The greater availability of certified seed, further reduces the use of home-saved seed.

Further scenarios with botanical seed prices of 25,000 and 50,000 ECU/kg. Still generate solutions that include the use of TPS technology. Their respective IGM is 39.6 and 14.8 million ECU. The observation that the ultimate effect of botanical seed price on the IGM is relatively small, is line with other studies. El Bedewy et al (1991) for example concluded that for Egypt, that the cost of the actual TPS amounted to only 2 % of the total production cost. He argued that an increase of TPS-cost by 350 % , would only increase the total production cost of seedling tubers by 5%. (El Bedewy et al., 1991).

8.3 The effect of TPS cultivation costs

Estimating the cost of potato production by means of direct seeding TPS proved to be difficult. In the previous scenario the model was run with a uniform first year cultivation cost of 4800 ECU per hectare The cultivation costs for subsequent years were taken to be identical to that of normal (seed, early, ware or starch) potato production. It is unlikely that the actual TPS cultivation costs will be identical throughout the Union, or even within one country. Initially it was hoped to use the costs and prices of comparable vegetable crops for different EU countries. Unfortunately, that was not possible. The model however can be run with different values for the cultivation costs. In this section the results will be examined of uniform first year cultivation costs for TPS of 2.4, 3.6, 4.8, 6.0, and 7.2 thousand ECU's per hectare. The full results of these scenarios are included in Appendix A.9. For all of the scenarios the world price for botanical seed has been used, and EU exports of seed tuber potatoes have been limited to 100,000 t/year. Under all of these scenarios TPS utilization proves to provide a positive IGM, as compared to the situation without the use of TPS. (see Figure 8.2)

Fig. 8.2 IGM and TPS use for different cultivation costs*.



* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.9 TPS use (kg) by country at different cultivation costs.

	Cultivation cost (ECU/ha)				
Country	2400	3600	4,800	6,000	7,200
Germany	1,424	1,499	1,487	1,487	1,487
France	0	184	0	0	0
Italy	1,509	1,701	1,718	1437	1,437
Netherlands	0	154	62	33	33
Denmark	359	359	0	0	0
Belgium/Lux	0	0	0	0	0
UK	2,356	2,293	1,462	151	151
Ireland	868	445	445	284	158
Spain	3,114	3,114	1,147	53	0
Portugal	1,315	1,315	698	698	698
Greece	465	465	271	271	17
TPS use (kg)	11,411	11,529	7,291	4,414	3,981
IGM (m ECU)	217.8	187.8	130.5	97.2	71.9

* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The effect of a 25 % change in the cultivation costs of TPS proves to be of a similar magnitude as a 100 % change in the price of the botanical seed. The way in which the countries would switch to TPS technology, however, also shows a picture that is noticeably different from that under the varying TPS-prices. (see Table 8.9). At the lower range of cultivation costs, the technology proves most attractive for application in the south of the EU Whereas with higher cultivation costs the trend reverses.

Table 8.10 Certified seed potato area (ha) at different TPS cultivation costs *

	Cultivation cost ECU/ha					
Country	**2400**	**3600**	**4,800**	**6,000**	**7,200**	**no TPS use**
Germany	32,315	32,595	32,629	32,629	32,629	25,194
France	12,381	13,213	12,381	12,381	12,381	12,935
Italy	7,546	8,503	8,589	7,184	7,184	2,117
Netherlands	28,085	27,992	33,025	35,337	35,337	35,457
Denmark	1,795	1,795	1,795	1,795	1,795	5,258
Belgium/Lux	0	0	0	0	0	1,543
UK	11,779	12,779	15,251	20,415	20,421	19,666
Ireland	4,340	2,227	2,227	1,806	2,323	2,641
Spain	15,569	15,569	15,737	10,267	10,000	10,000
Portugal	6,577	6,577	3,489	3,489	3,489	403
Greece	2,325	2,326	1,357	1,357	84	435
EU-12	122,712	123,576	126,480	126,660	125,643	115,649

* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.10 (see above) shows the seed areas of the respective countries follow their use of TPS technology. At the low range of cultivation costs, Spain, Portugal and Greece would use a larger certified seed area than under the high range of the cultivation costs.

The changes in cultivation cost would have no noticeable impact on the trade of seed potatoes within the EU. The trade flows closely resemble those presented in the Tables 8.3 and 8.4. The same limitations towards the reliability of trade data apply.

Table 8.11 Ware potato area ('000 ha) at different TPS cultivation costs*.

	Cultivation cost ECU/ha					
Country	**2400**	**3600**	**4800**	**6000**	**7200**	**no TPS use**
Germany	215.5	215.1	215.1	215.1	215.1	220.8
France	100.5	99.6	100.5	100.5	100.5	100.0
Italy	73.6	72.0	73.1	75.3	75.3	86.2
Netherlands	80.7	80.7	80.7	80.7	80.7	80.5
Denmark	18.2	18.2	18.2	18.2	18.2	14.8
Belgium/Lux	50.0	50.0	50.0	50.0	50.0	48.5
UK	148.2	148.2	144.7	139.6	139.0	140.3
Ireland	12.7	14.7	14.8	15.2	14.6	14.9
Spain	184.4	184.4	187.3	209.1	210.7	213.0
Portugal	61.9	61.9	66.5	66.5	66.6	91.6
Greece	13.9	13.9	15.3	15.3	18.9	37.6
EU-12	959.2	958.7	966.2	985.5	989.6	1,048.2
reduction of potato area	83.1	83.1	71.9	52.5	48.6	0

* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The effect of changing cultivation costs on the ware potato area (see Table 8.11) is similar to changing the botanical seed price (see Table 8.5). The reason being that the absolute demand for ware potatoes does not change with the type of planting material used for potato production. The ware area is most effected by reductions in the use of home-saved seed. Once that use has been brought down to zero, no further reductions in ware area can be expected. At the botanical seed price of 2400 ECU/kg and cultivation costs of 4800 ECU/ha, the use of certified seed tubers is 100 %. At the cultivation cost of 7200 ECU/ha, the use of certified seed tubers has fallen back to 89 %, thus making a larger ware production area necessary.

Cultivation costs have a knock-on effect on the early and starch sectors that is similar to that of the ware sector. The use of home-saved seed would be expected to fall with the lowering of the cultivation costs. The reduction of early imports from non-EU countries is slightly more a consequence of lower cultivation costs, than it is of lower botanical seed prices.

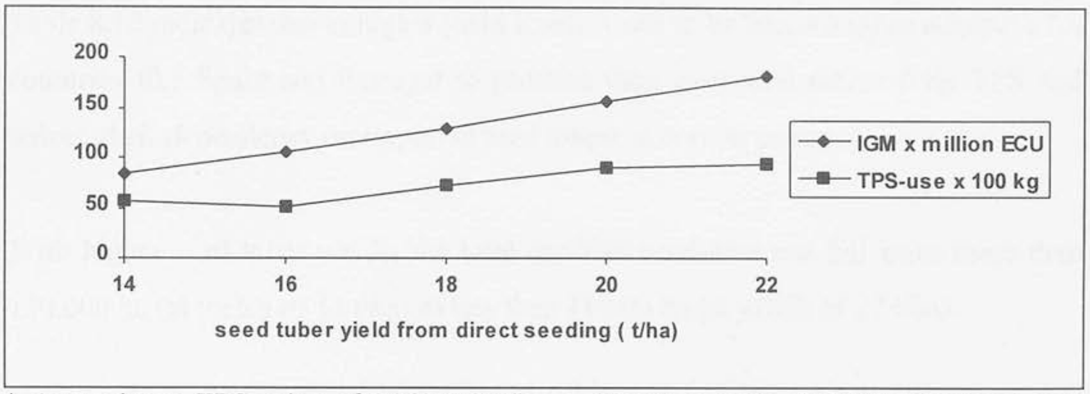
8.4 The effect of seed tuber yield from the direct seeding.

So far all scenarios have assumed that the seed tuber yield from direct seeding of TPS is 18 t/ha In commercial circumstances significant deviations of this yield have been reported (Merwe, 1997; Van Hest, 1996), ranging from as low as five t/ha after adverse whether conditions just after seeding to more than 40 t/ha under optimal conditions in California the actual yield achieved from direct seeding will depend greatly on the skill and experience of the growers, as well as on the weather and field conditions during the growing season.

This section examines five different seed tuber yield scenarios, of 14 , 16, 18, 20, and 22 t/ha respectively. The current world price for botanical seed is used and EU export of seed potatoes is limited to 100,000 t for all situations. (see Appendix A.9.)

The modeling results indicate that the use of TPS technology is beneficial, even at average yields more than 20 % below the expected average (see Figure 8.3).

Fig. 8.3 IGM and TPS use for different yields from direct seeding.



* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

From Figure 8.3 and Tables 8.12 and 8.13, it appears that small changes in the seed tuber yield has a large impact on the optimal solution.

Table 8.12 TPS use (kg) at different yield levels from TPS seeding*.

Country	Seed tuber yield (t/ha) 14	16	18	20	22
Germany	605	1,657	1,487	1,349	1,540
France	0	0	0	165	0
Italy	1,860	1,616	1,718	1,505	1,360
Netherlands	33	70	62	0	0
Denmark	17	0	0	526	544
Belgium/Lux	0	0	0	0	0
UK	190	115	1,462	1,760	1,884
Ireland	359	397	445	507	588
Spain	69	185	1,147	2,201	2,001
Portugal	897	785	698	628	1,076
Greece	354	305	271	419	380
IGM (m ECU)	83.6	106.5	130.5	156.4	182.0
TPS use (kg)	5,650	5,131	7,291	9,060	9,375

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.12 indicates that at higher yield levels it would be become more attractive for countries like Spain and Portugal to produce their own seed tubers from TPS and reduce their dependency on imported seed tubers at current prices.

With higher seed tuber yields, the total certified seed area can fall from more than 130,000 ha (at yields of 14 t/ha) to less than 110,00 ha (at yields of 22 t/ha).

Table 8.13 Certified seed potato area (ha) at different yield levels from TPS seeding*.

	Tuber yield (t/ha)					
Country	14	16	18	20	22	No TPS
Germany	34,547	34,479	32,629	31,938	30,012	25,194
France	12,381	12,381	12,381	13,126	12,381	12,935
Italy	9,300	8,082	8,589	7,526	6,803	2,117
Netherlands	35,337	35,189	33,025	28,438	24,015	35,457
Denmark	1,795	1,795	1,795	2,632	2,719	5,258
Belgium/Lux	0	0	0	0	0	1,543
UK	20,615	20,241	15,251	11,779	11,779	19,666
Ireland	1,793	1,986	2,227	2,534	2,940	2,641
Spain	10,343	10,925	15,737	11,006	10,006	10,000
Portugal	4,486	3,925	3,489	3,140	5,381	403
Greece	1,772	1,527	1,357	2,093	1,903	435
EU-12	132,369	130,530	126,480	114,212	107,939	115,649

* Assuming cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Only when the yields from direct seeding go beyond the 20 t/ha level, does the level of the internal EU seed tuber trade decrease, although not dramatically. Apparently, it is still comparatively advantageous to import seed tubers from traditional countries.

In line with the increased use of certified seed, the area used for ware potato production will fall, as well as the total area needed for potato production (see Table 8.14).

Table 8.14 Ware potato area ('000 ha) at different yield levels from TPS seeding*.

	Seed tuber yield (t/ha)					
	no TPS	**14**	**16**	**18**	**20**	**22**
Germany	220.8	213,2	214.3	215.1	215.8	217.7
France	100.0	100.5	100.5	100.5	99.7	100.5
Italy	86.2	75,3	75.3	73.1	70.3	69.8
Netherlands	80.5	80.7	80.7	80.7	80.7	80.7
Denmark	14.8	18.2	18.2	18.2	17.4	17.2
Belgium/Lux	48.5	50.0	50.0	50.0	50.0	50.0
UK	140.3	139.4	139.7	144.7	148.2	148.2
Ireland	14.9	15.2	15.0	14.8	14.5	14.1
Spain	213.0	212.6	209.1	187.3	187.2	187.3
Portugal	91.6	66.5	65.5	66.5	66.5	61.9
Greece	37.6	15.5	15.3	15.3	13.9	13.9
EU-12	1,048.2	987.1	983.6	966.2	964.2	961.3
reduced potato area (ha)	0	45.0	50.3	71.9	86.1	83.9

*Assuming a TPS price of 2460 ECU/ha, cultivation costs of 4800 ECU/year and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

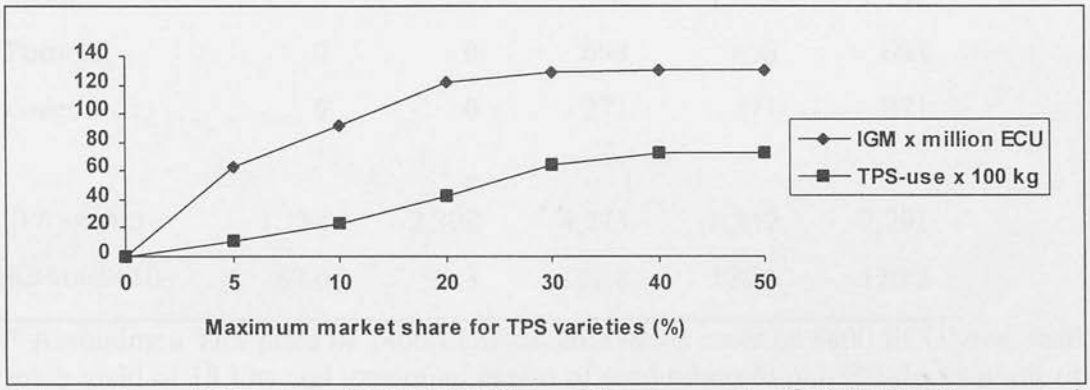
The effects of increased seed tuber yield from TPS on the early and starch sector would be similar to that of reduced cultivation costs and lower botanical seed prices.

Explorations of seed tuber yield scenarios as low as 9 t/ha still indicate optimum solutions that included the use of TPS technology, with an IGM of just over 19 million ECU and TPS use of 2,943 kg. The attractiveness of the technology at such a low yield can be explained by the fact that it allows a large expansion of the certified seed tuber area. At these low yields, 85 % of the TPS utilization would take place in Italy, increasing the seed tuber production area from 2,117 ha to 12, 651 ha.

8.5 Limited acceptance of TPS varieties

All scenarios so far discussed have assumed that the TPS varieties from the USA are capable of substituting all of the existing EU-clonal potato varieties. Based solely on potato production costs, the optimal solutions predict a market share for TPS varieties of almost 40 %. Higher market shares would reduce the value of the IGM, and are unlikely to occur in a profit maximizing situation. It is unlikely that the nine TPS varieties that are commercially available in the USA, would be able to meet 40 % of the EU's consumer demands. To explore the attractiveness of the technology at a limited consumer acceptance of the new potato varieties, the model has been run whilst limiting the market share of TPS varieties to 5, 10, 20 , 30 and 40 %. It is been assumed that TPS would become available at world market prices, that the export of EU seed potatoes would be reduced to 100,000 t/ year. The full results are included in Appendix 8.

Fig. 8.4 IGM and TPS use at different acceptance levels for TPS varieties*.



* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of

100,000 t/year.

From Fig. 8.14 and Table 8.15 it show that the IGM would rise most rapidly over the market share range of 0 to 20 %. From 20 to 40 % the IGM increases only by some 6.5 % in value. Even at the lower market share of 5 %, the IGM would be nearly half of the maximum value that achieved with a market share of about 40 %. With lower market share, most of the TPS will be used by Germany and Italy. (See Table 8.15) In Germany, the increased availability of certified seed would lead to an increased output of ware potatoes. For Italy the same would take place with the production of early potatoes.

Table 8.15 TPS use (kg) at different acceptance levels of TPS varieties*.

	Acceptance level				
Country	**< 5%**	**< 10 %**	**< 20 %**	**< 30 %**	**< 40 %**
Germany	759	1,349	1,487	1,487	1,487
France	0	0	0	0	0
Italy	209	768	1,359	1,437	1,718
Netherlands	0	0	26	62	62
Denmark	0	0	0	0	0
Belgium/Lux	0	0	0	0	0
UK	151	151	151	1,103	1,462
Ireland	35	40	280	445	445
Spain	0	0	0	1,008	1,147
Portugal	0	0	698	698	698
Greece	0	0	271	271	271
TPS use (kg)	1,154	2,308	4,273	6,512	7,291
IGM (m ECU)	63.0	91.3	121.8	128.6	130.5

* Assuming a TPS price of 2460 ECU/ha, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Table 8.16 Certified seed potato area (ha) at different TPS acceptance levels

	Acceptance level					
Country	**< 5 %**	**< 10 %**	**< 20 %**	**< 30 %**	**< 40 %**	**no TPS use**
Germany	28,988	31,627	32,629	32,629	32,629	25,194
France	12,315	12,381	12,381	12,381	12,381	12,935
Italy	1,045	3,838	6,797	7,184	8,589	2,117
Netherlands	35,337	35,337	35,337	34,829	33,025	35,457
Denmark	5,258	5,258	2,374	1,795	1,795	5,258
Belgium/Lux	0	0	0	0	0	1,543
UK	20,420	20,421	20,421	16,454	15,251	19,666
Ireland	2,816	2,843	1,403	2,227	2,227	2,641
Spain	10,000	10,000	10,000	15,040	15,737	10,000
Portugal	0	0	3,489	3,489	3,489	403
Greece	194	194	1,357	1,357	1,357	435
EU-12	116,373	121,899	126,188	127,385	126,480	115,649

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

As expected, the total certified seed tuber area for the EU will increase with an increase in market share for TPS varieties. (See Table 8.16.)

The area needed for ware production would fall when the use of TPS technology increases. The largest reduction of total potato area takes place when the market share increases over the range 0 to 20 %. (See Table 8.17).

Table 8.17 Ware potato area ('000 ha) at different TPS acceptance levels *.

	Acceptance					
Country	**0 %**	**< 5 %**	**< 10 %**	**< 20 %**	**< 30 %**	**< 40 %**
Germany	220.8	217.0	214.0	215.1	215.1	215.1
France	100.0	100.4	100.5	100.5	100.5	100.5
Italy	86.2	86.8	62.9	75.3	75.3	73.1
Netherlands	80.5	80.7	80.7	80.7	80.7	80.7
Denmark	14.8	14.8	14.8	17.6	18.2	18.2
Belgium/Lux	48.5	50.0	50.0	50.0	50.0	50.0
UK	140.3	139.6	139.6	139.6	143.5	144.7
Ireland	14.9	14.6	14.1	15.2	14.8	14.8
Spain	213.0	213.0	213.0	211.2	189.0	187.3
Portugal	91.6	78.8	78.8	66.5	66.5	66.5
Greece	37.6	37.8	28.5	15.3	15.3	15.3
EU-12	1,048.2	1033.5	996.9	987.0	968.9	966.2
Reduction in potato area	0	13.3	27.5	51.0	68.2	71.9

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

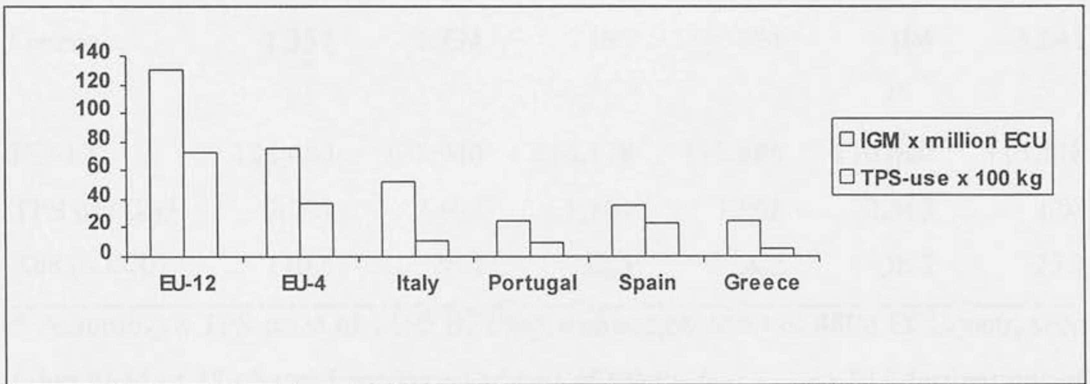
At smaller market shares for TPS varieties, the impact on the early and starch sectors will be even smaller as described previously with the scenario of varying prices for the botanical seed.

8.6 The impact of regional limitations on the uptake of TPS technology.

The four southern most countries of the EU; Portugal, Spain, Italy and Greece account for 35 % of the EU potato growing area, but only 11 % of the certified seed tuber area. For this reason, these countries are forced to either import seed potatoes from northern Europe, or use home-saved seed. This structural shortage of certified seed, and the somewhat less stringent market standards for ware potatoes, make these countries obvious candidates for an early uptake of TPS technology. In this section the use of TPS technology, limited to these four countries as a whole, and for each country individually will be explored. Again, the current world market price for botanical seed is used, together with cultivation costs of 4800 ECU/ha, a yield of 18 t/ha and a reduction in the EU seed potato exports to 100,000 t. per year. The full modeling results are in Appendix A.9.

Figure 8.23 and Table 8. 24 indicates that TPS technology still generates an IGM of between 24 and 53 million ECU when its use is restricted to just a single country, (Portugal and Italy respectively).

Fig. 8.5 IGM and TPS use for different regional limitation to the uptake of TPS*.



* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

Even when the use of TPS-technology is limited to just one, or all four of the southern EU countries, the knock-on effect on the whole of the EU seed sector is noticeable. Because less certified seed tubers needs to be exported to the south, more of such certified seed would become available for countries in the north. They could reduce the use of home-saved seed, and improve the average yield per hectare.

Similarly, for countries in the south, the use of home-saved seed will fall, and average yields will rise.

Table 8.18 Certified seed potato area (ha) at different regional limitations*.

	TPS use limited to:					
Country	**EU-12**	**EU-4**	**Italy**	**Portugal**	**Spain**	**Greece**
Germany	32,629	25,194	25,194	25,194	25,194	25,194
France	12,381	12,381	12,381	12,381	12,381	12,381
Italy	8,589	4,907	5,507	0	0	0
Netherlands	33,025	35,337	35,337	35,337	35,337	35,337
Denmark	1,795	5,258	5258	5,258	5,258	5,258
Belgium/Lux	0	0	0	0	0	0
UK	15,251	19,666	19,666	19,666	19,666	19,666
Ireland	2,227	2,641	2,641	2,641	2,892	2,641
Spain	15,737	17,273	10,000	10,000	15,098	10,000
Portugal	3,489	3,489	0	5,015	0	0
Greece	1,357	2,794	194	194	194	3,041
EU-12	126,480	128,940	116,178	115,686	116,020	113,518
TPS use (kg)	7,291	3,693	1,101	1,003	2,363	608
IGM (m ECU)	130.5	75.5	52.3	24.2	36.3	25.3

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The EU-wide impact of the use of TPS technology when used by only one country, will vary according to the size of the respective potato industry and the revenues of alternative land uses in that country. The IGM of TPS in Spain (potato area 266,000) will obviously be larger than that of Greece (potato area 52,000). Countries like Italy and Portugal, which have a similar size of potato growing area, would still reduce their potato growing area but with quite different IGM. This is due to the fact that Italy's average ware yield is almost twice that of Portugal, and because the alternative revenues for arable land in Italy are higher. The projected ware production areas for the these scenarios are listed in Table 8.19.

Table 8.19 Ware potato area ('000 ha) at different regional limitations *.

	TPS use limited to:					
Country	**EU-12**	**EU-4**	**Italy**	**Portugal**	**Spain**	**Greece**
Germany	215.1	220.8	220.8	220.8	220.8	220.8
France	100.5	100.5	102.3	100.5	100.5	100.5
Italy	73.1	75.3	82.48	88.7	88.7	88.7
Netherlands	80.7	80.7	80.7	80.7	80.7	80.7
Denmark	18.2	19.4	14.8	14.8	14.8	14.8
Belgium/Lux	50.0	50.0	50.0	50.0	50.0	50.0
UK	144.7	140.3	140.3	140.3	140.3	140.3
Ireland	14.8	14.4	14.9	14.7	14.4	14.7
Spain	187.3	205.7	213.0	213.0	207.8	213.0
Portugal	66.5	66.5	78.8	84.0	78.8	91.4
Greece	15.3	35.5	37.8	37.8	37.8	35.0
EU-12	966.2	1,009.1	1,035.9	1,045.3	1,034.6	1,049.9
Reduction of potato area	71.9	32.5	13.2	2.9	13.2	0.6

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

The impact of TPS use on the areas needed for early potatoes is less pronounced, (see Table 8.20) and might well be under represented by this model. Since early potatoes generate higher revenues per hectare than ware potatoes, the model automatically favors this activity for the use of certified seed. Thus in the basic solution (without the use of TPS) the early potato growing activities already use a high percentage of certified of seed. Starting at such a high level, means that there is little room for improvement. Unfortunately, the assumptions about the use of home-saved/ certified seed for the production of early potatoes could not be checked against any reliable data.

Table 8.20 Early potato area ('000 ha) at different regional limitations *.

	TPS use limited to:					
Country	**EU-12**	**EU-4**	**Italy**	**Portugal**	**Spain**	**Greece**
Germany	25.0	25.0	25.0	25.0	25.0	25.0
France	24.0	24.0	22.2	24.0	24.0	24.0
Italy	30.0	30.0	30.0	29.3	29.3	29.3
Belgium/Lux	8.0	8.0	8.0	8.0	8.0	8.0
UK	16.0	16.0	16.0	16.0	16.0	16.0
Ireland	3.0	3.0	2.4	2.6	3.0	2.6
Spain	43.0	43.0	43.0	43.0	43.0	43.0
Portugal	17.0	17.0	17.0	17.0	17.0	17.0
Greece	14.0	14.0	0	14.0	14.0	14.0
EU-12	180.0	180.0	163.6	178.9	179.3	178.9
Imports from non EU (t)	353,250	389,000	437,033	443,620	443,620	447,000

* Assuming a TPS price of 2460 ECU/kg, cultivation costs of 4800 ECU/year, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 100,000 t/year.

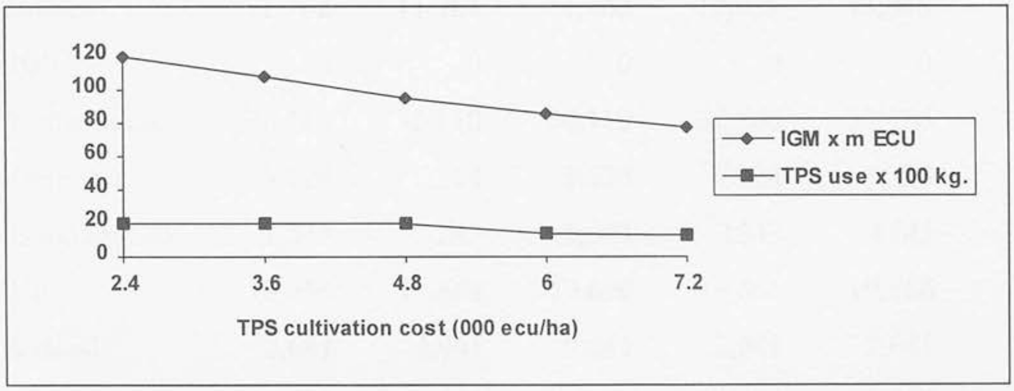
The model does not represent any starch producing activities in the four southern EU countries. The use of TPS in these countries would have no influence on the starch production in Germany, The Netherlands, France or Denmark.

8.7 The impact of TPS technology when limited to the starch sector

Finally, scenarios whereby the TPS varieties and technology are deemed only suitable for starch production are explored. Since the starch sector does not pay attention to skin finish, flesh color or uniformity other than for starch content, this sector appears to have the lowest barriers towards the uptake of TPS-technology. Here it is assumed that TPS becomes available at world market prices, and yields 18 t of seed tubers per hectare. Since the TPS-use is limited to the starch sector, the export limit for seed potatoes from the EU has not been lowered, but maintained at 250,000 t/year. Again, the full modeling results are included in Appendix 8.

The use of TPS in this context seems to be beneficial to the EU (See Figure. 8.6) The increased availability of certified seed raises the average yield for the starch production area. Since the total demand is fixed, the sector can meet its obligations from a smaller area, thus freeing up land for the production of seed and ware potatoes for export markets.

Fig 8.6 IGM and TPS use at different cultivation costs, when limited to the starch sector*.



* Assuming a TPS price of 2460 ECU/ha, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 250,000 t/year.

Table 8.21 Summary of results for TPS use, when restricted to the starch sector*.

	Cultivation cost (ECU/ha)					
	2400	**3600**	**4800**	**5000**	**7200**	**no TPS use**
IGM (m ECU)	134.3	107.8	95.7	85.6	77.7	0
TPS use (KG)	2,011	2011	2011	1357	1257	0
Reduced potato area	6,420	6,420	6,420	1,286	0	0

* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 250,000 t/year.

The use of TPS technology would allow for a significant increase in the certified seed area especially in Germany, and eliminates the use of non-TPS-varieties for the production of starch (see Table 8.21)

Table 8.22 Certified seed potato area (ha) when TPS is restricted to starch sector*.

	TPS cultivation cost ECU/ha					
Country	**2,400**	**3,600**	**4,800**	**6,000**	**7,200**	**no TPS use**
Germany	35,255	35,253	35,251	31,980	31,481	25,194
France	11,762	11,761	11,762	13,939	13,940	12,935
Italy	0	0	0	0	0	2,117
Netherlands	36,110	36,110	36,110	37,166	37,166	35,457
Denmark	5,224	5,224	5,224	5224	5,225	5,258
Belgium/Lux	1,543	1,543	1,543	1543	1543	1,543
UK	19,666	19,666	19,666	19,666	19,666	19,666
Ireland	2,641	2,641	2,641	2,641	2,641	2,641
Spain	10,000	10,000	10,000	10,000	10,000	10,000
Portugal	0	0	0	0	0	403
Greece	194	194	194	435	435	435
EU-12	122,395	122,394	122,391	122,594	122,097	115,649

* Assuming a TPS price of 2460 ECU/kg, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 250,000 t/year.

As expected, the use of TPS technology allows for a reduction in the total EU starch production area. (See Table 8.22.).

Table 8.23 Starch potato area (ha) when the use of TPS is limited to starch sector*.

	Cultivation cost/ha					
Country	**2400**	**3600**	**4,800**	**6,000**	**7,200**	**No TPS use**
Germany	69,231	69,231	69,231	69,231	69,231	70,998
France	34,139	34,139	34,139	34,139	34,139	34,139
Netherlands	57,620	57,620	57,620	63,999	63,999	63,999
Denmark	22,316	22,316	22,316	22,316	22,316	22,982
EU-12	183,306	183,306	183,306	189,685	189,685	192,118

* Assuming a TPS price of 2460 ECU/ha, seed tuber yield of 18 t/ha and maximum export of seed tubers to non EU-destinations of 250,000 t/year.

8.8 Summary

In the scenario whereby USA-style TPS technology becomes available to the EU potato industry, with the standard assumptions[1], the modeling results can be summarized as follows;

i Improvement of the gross margin of the industry as a whole by 130 million ECU per year.
ii Reduction of the land needed for the cultivation of potatoes by 70,000 hectares.
iii Virtual elimination the use of uncertified home-saved seed potatoes.
iv Increased national average yields for ware, early and starch potatoes because of

[1] TPS price = 2460 ECU/Kg, yield from TPS = 18 t/ha, cultivation cost = 4800 ECU/ha, no restrictions to regions or market share

the increased use of certified seed.

The LP model has also been run for a large number of scenarios with different values for important parameters such as TPS-price, cultivation cost, yield, geographic limits to the uptake and market share of TPS varieties. The critical minimum and maximum values of these parameters, at which the IGM is still positive, are summarized in Table 8.24

Table 8.24 Critical values of parameters that still generate a positive IGM.

Parameter	Minimum	Maximum	Corresponding assumptions
TPS-price (ECU/Kg)	N/a	> 50,000	TPS yield = 18 t/ha Cultivation cost = 4800 ECU/ha
Yield of TPS (t/ha.)	< 9	N/a	TPS price = 2460 ECU/kg Cultivation cost = 4800 ECU/ha
Cultivation cost (ECU/ha.)	N/a	> 9,600	TPS price = 2460 ECU/kg TPS yield = 18 t/ha
Uptake by Country	1	N/a	TPS price = 2460 ECU/kg TPS yield = 18 t/ha Cultivation cost = 4800 ECU/ha
Market share (%)	< 1	100	TPS price = 2460 ECU/kg TPS yield = 18 t/ha Cultivation cost = 4800 ECU/ha

Based upon the modeling results for various values of the important parameters the following general conclusions can be drawn;

1 TPS-price; The impact of the technology will be reduced, although not very much, by an increase of the TPS price. Even at TPS prices that are several times

higher than the world market price, the use of TPS technology would be economically advantageous.

2 TPS-Cultivation costs; Scenario's whereby the cost of cultivating TPS were 50 % higher than the standard assumed cost of 4800 ECU/ha , still resulted in a positive IGM and release of potato land. However a 10 % increase in cultivation costs had a much greater negative impact than a 10 % increase in TPS-price.

3 TPS-yields; variations in assumed seed tuber yield from TPS proved of great influence on the modeling results. Although, even at yields as low as 9 t/ha, the technology proves to be of benefit to the EU potato industry.

4 Acceptance of TPS-varieties proved to be a limiting factor on the size of the expected benefits, especially when the level of acceptance would fall below 20 %.

5 Limitations on use of TPS technology to one or more of the four southernmost countries of the EU, would still generate a positive IMG.

6 Even when the use of TPS would be restricted to only the starch potato sector, the effect on the EU potato industry as a whole would be beneficial in terms of a positive IGM and release of land.

To fully appreciate the modeling results, the following factors will have to be taken into account;

1 The IGM does not take account of the costs or time needed to introduce USA-style TPS technology into the EU. If they where to be included in the assessment, the IGM would be lower.
2 The IGM does not account for the saving that will occur within a country, as a result of the use of TPS technology. For some large countries like Italy the savings of for instance internal transportation costs of seed from the North to the south can be large. If the savings within individual countries where to be

included in the assessment, the IGM would be higher.

3 The model assumes that the nine TPS varieties that are currently available will jointly be capable to fulfill the needs for a large part of the consumer market. Although it is not uncommon for a few potato varieties to dominate an industry (Maris Piper, Bintje, Russet Burbank) it is unlikely that these first commercial TPS varieties will immediately be capable to capture such a high market share. Additional TPS varieties will have to be developed for that purpose. If these factor were to be included in the assessment, the IGM would be lower.

4 The model does not put a value upon the savings in the use of pesticides, chemicals and fossil fuels because of TPS technology. If they were included into the assessment, the IGM would be higher.

5 The model is based upon a representative year, whereby supply and demand are broadly in balance. In years of over supply, the value of the IGM is expected to be lower, since more farmers will chose to plant uncertified seed of their excess production. In years of a shortage in supply the value of the IGM is expected to be higher, since TPS technology allows for a rapid increase in the planted area.

After considering the limitations of the LP-model as outlined above, and based up on the range of most likely uptake scenarios and their reported outcomes, the null hypothesis, that the use of USA-style TPS-technology is beneficial to the EU potato industry, -has not been not rejected.

9. DISCUSSION AND CONCLUSION

9.1 Introduction

This study sets out to make a contribution towards the ongoing discussion in the potato industry about the potential role and economic value of TPS technology. A mathematical model has been used as the main form of methodology, and it was concluded that substantial benefits can be expected from the use of TPS technology by the EU potato industry. Provided that is, that the quality of the potatoes produced with TPS-technology are capable of meeting the minimum standards of the market. This chapter will evaluate the use of mathematical modeling for the assessment of TPS technology, and ways in which this methodological tool can be improved upon (9.2). Section 9.3 discusses the prospective role of TPS technology in the EU, and section 9.4 looks at some of the four most important barriers to the actual uptake of this technology within the EU. Section 9.5 identifies some topics that should be placed high upon the TPS research agenda. Final conclusions and remarks about this study and the potential of TPS technology are stated in section 9.6.

9.2 Evaluation of the methodology

The primary limitation to the use of mathematical modeling is the availability of reliable data, from which a model can be built and validated. This limitation appears to be inherent to the complex nature of the EU potato industry, and any other methodology such as an econometric model would be at least equally handicapped by the same lack of data. Against this background, the use of a mathematical model proved workable and capable of identifying the magnitude and direction of changes that are likely to occur from the use of TPS technology.

Several factors indicate that the model that has been used for this study, actually underestimates the economic impact of the changes. No account is taken of the fact that given a choice, agricultural production will concentrate itself on the most fertile grounds, thus raising the average production disproportionately to any reduction of land. If the use of TPS technology follows the same trend, it would cause less productive potato land to be taken out of production.. The model does not take account either of the economies of scale that are likely to occur with the use of a technology like TPS. The "better" farmers will be able to generate more profits from the technology, and thus force farmers that produce at a higher cost per tonne out of the market.

The model identifies the actual minimum costs of transportation between countries, but it does not recognize the savings in transport costs that are likely to occur within countries. At present Italian seed potato production is concentrated in the utmost north of the country. From there it is transported at considerable cost to ware producers down south. With TPS technology it will be possible to produce healthy seed potatoes much closer to these ware growers, and thus save on transportation costs. The model does not identify either, the savings that are likely to occur when layers of middlemen and their margins can be eliminated because of an alternative way of seed potato provision.

The use of TPS technology is also expected to have a beneficial impact on the use of chemicals and pesticides, since healthier seed will require less artificial assistance to produce a healthy ware crop. The increase of certified seed use can in the long term also help to clean up entire areas of soil diseases that are currently spread and maintained by the use of home saved seed. The potential impact of TPS on these areas has not been included in the model for a lack of available data. That does not mean however that such an impact should be ignored.

The most important factors that have been included and excluded from the assessment of the impact of TPS technology have been summarized in Table 9.1.

Table 9.1 Factors included and excluded from the calculation of the IGM.

Included factors	**Excluded factors**
• Price of TPS • Cultivation cost for TPS and potato plantings. • Yields from TPS and potato plantings. • Differences in potato production characteristics between EU countries • Regional differences in the uptake of TPS technology. • Market acceptance of TPS-varieties • Storage costs of potatoes. • Transport costs between countries. • Price difference between different market segments per country. • Effect on EU exports and imports.	• Cost of introducing TPS technology. • Cost of generating TPS technology. • Transport costs savings within countries. • Effects of overproduction or under supply to the market place. • Differences in potato production characteristics within countries. • Reactions of current suppliers of seed potatoes, e.g. dumping. • Reductions of chemicals and fossil fuels. • Price differences between different potato varieties and tuber sizes. • Impact differences between farms of different size and structure • Profit margins of middlemen.

Since the model proved functional for the assessment at an EU-wide scale, it would be useful to develop subsequent mathematical models for smaller geographical areas, of which more information could be obtained. In this respect it would be most interesting to make a detailed model of countries like Germany, Italy and Spain, which according to this model would definitely use TPS technology. One could also consider building a multi-level model to simulate the trade-off of gains and losses between EU countries as a result of this technology. Substantially more data would have to become available to make such a model function. More detailed models of smaller regions would help to identify more accurately what kind of benefits can be expected from TPS technology in the EU.

9.3 The prospective role of TPS in the European Union

All the results from this study indicate that TPS-technology could come to play an important role in the EU potato industry. The market share of TPS varieties could become as high as 40 %, in the situation whereby TPS can be bought at the world market price of 2460 ECU/kg, cultivated at a cost of around 4800 ECU/ha and produce from the botanical seed, 18 tonnes of seed tubers per hectare. A switch towards the use of TPS technology in the EU is unlikely to take place abruptly within the next few years. As with any large and complex industry, that employs more than a million people, change is best managed as a gradual process. The uptake of TPS would most likely take place in three waves, starting with the starch industry, followed by the countries of southern Europe and finally some countries in northern Europe.

The starch sector would be among the first to start using TPS technology. The widely heard argument that TPS varieties produce potatoes with limited tuber uniformity has no bearing on this sector. Neither the color of the skin and flesh, nor the taste of the potatoes has any effect on the starch content, which is the only part of the potato that is being used. Furthermore the starch sector uses around 17 % of the EU potato area, and is controlled by only a handful of companies. The Dutch co-operative AVEBE alone already produces more than 60 % of the EU starch potatoes, and to them the technology is definitely an interesting option (Rus,1995). This co-operative is interested in a cheaper supply of healthy seed tubers, and if the starch content of the TPS-varieties and the price-structure were right, it would seriously consider switching over to TPS technology (Rus, 1995).

The advantages of TPS use to the starch industry would come in the form of reduced costs for the purchase of certified seed tubers, and the release of some land that could be used for other forms of agricultural production. The limited number of organizations involved in this sector, implies that change could happen much faster than in a sector of similar size, consisting of several thousand organizations.

The second wave of TPS uptake would be expected in the countries of southern Europe (Portugal, Spain, Italy and Greece). Potato production in these countries is characterized by large imports of seed tubers from northern Europe and a relative large use of (uncertified) home-saved seed. As suggested by Fruscianti et al. (1987) and others, TPS technology would be a suitable alternative for Italy and countries with a similar potato industry. The countries in the south of the EU would benefit from the technology by increasing the use of certified seed tubers, and thus raising the average yields of ware and early potatoes. As a result of the higher average yields, several thousand hectares of potato land will become available for alternative uses. These countries would also become more competitive in their cost structure for the production of early potatoes, which would increase their export potential to markets in northern EU countries. In addition to that, the use of TPS technology in the four southernmost countries would lead to EU-wide savings of up to 75 million ECU/year.

The third and last wave of TPS uptake would take place in those countries of northern Europe where resistance to TPS-varieties is thought to be the strongest. The fresh markets in the north of the EU place very high demands on the skin color and flesh color of ware and early potatoes. The consumers in these countries would most likely encounter the potatoes from TPS varieties in the form of early imports from southern Europe. Having become accustomed to importing these varieties, the switch to growing them would be a relatively minor change. Countries in the north of the EU would benefit from the use of TPS by reducing their cost of producing certified seed, by increasing their average ware and early yields because of a lower use of uncertified home-saved seed, and by the release of several thousand hectares of land from potato production.

Although it is generally thought that countries in the north of the EU would be amongst the latest to switch over to TPS varieties, some indications to the contrary exist. For high street supermarkets like Marks & Spencer, the concepts of TPS man be very attractive. The yields from direct seeding would not be used for further multiplication, but would be sold as organically friendly grown baby potatoes, attracting high margins for both the growers as the retailer (Sharp, 1996).

9.4 Barriers to the uptake of TPS technology in the EU

Even though the prospects of TPS technology in the EU appear to be good, several barriers will hinder the uptake of this technology. Four of the most important ones will be discussed here, namely: (a) the supply of TPS (b) the acceptance of TPS varieties (c) the technical learning curve and (d) the resistance to change within the EU potato industry.

a) The supply of TPS

A first barrier for the uptake of TPS technology consists of any shortfalls to an adequate and unhindered supply of TPS to the farmers who are willing to switch over to this form of seed potato production. At present it is not possible for them to import TPS from any of the non-EU countries, where TPS production is currently taking place on a large scale. Within the EU no commercial TPS production facilities exist at the moment.

However, the results from this study (especially 8.2) indicate that the use of TPS technology would still be beneficial at a TPS price level that is two or even three times the world market price. This leads to the conclusion that it would be commercially viable to produce TPS within an EU country for the purpose of using it in the Union. The cost savings and release of land would still be substantial.

The setting up of a TPS production facility within the EU would incur start up costs of the order of two to three million ECU. The starting up period before the first TPS could be harvested would be at least two years (one to import and multiply the parental material and a second one to produce the actual TPS). The financing of such a TPS production facility is a risky activity, as long as there is little information about how fast the market will actually switch over to using TPS. Such uncertainty will make it difficult to attract the funding that is needed, and will hamper the arrival of TPS on the EU market.

Even a temporary lifting of the import ban on TPS would be very advantageous for the advancement of this technology. For it would allow the seed tuber producing sector to experiment with the technology, without having to make great capital expenditures. In this respect the observation seems to holds true that,"*..the progress and application of TPS technology may lie in the hands of politicians, rather than scientists*." (Almekinders, et al. 1996).

b) The acceptance of TPS varieties

The potatoes that are grown by the use of TPS technology will be new potato varieties. The literature suggests that the varietal change-over rate in potatoes is very low, which makes it difficult for any new variety to obtain a market share at the expense of older and established varieties (Walker, 1994). Even when a new variety possesses many of the qualities that are similar to one of the leading varieties, and might even be better in several aspects, market acceptance can be very slow. At the end of the day consumers and grower will have to be willing to eat and cultivate the potatoes that can be grown from TPS varieties. Currently there is a complete absence of information about the attitudes of the EU consumer to the TPS varieties that have been bred in the USA (or elsewhere). Therefore few growers will be willing to risk growing these new varieties, when there are much more "safer" alternatives available in the form of well established clonal varieties.

c) The technological learning curve

The cultivation of potatoes from botanical seed is a horticultural activity, which is uncommon amongst both traditional potato growers and vegetable growers. Although the potato seeds may be of similar size as that of the tomato plant, that does not mean that they can be grown in exactly the same way. Acquiring the skill to successfully grow potatoes from TPS takes several seasons, during which sub-optimal yields will have to be accepted. Since only limited information is available about the technical aspects of the direct seeding of TPS, the early users of this technology will find themselves short of the usual kind of support (e.g. extension service, literature, colleagues) that is widely available to traditional potato growers in the EU.

d) Institutional resistance

Like any institution, the potato industry has an inherent resistance to any form of change, which in itself is not related to the specific characteristics of TPS technology. The Italian writer Machiavelli made the following observation about the political power play that works against any effort to change or improve the status quo, *''For he who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might be better off under the new "(Machiavelli (1992), The Prince, Chapter VI).*

Examples of the above principle can easily be found in the case of TPS technology; In the early 1990s for instance TPS technology made big inroads in Nicaragua, leading to a situation whereby up to 60 % of all potatoes in the market were grown from TPS-varieties. The use of TPS proved to be considerably cheaper than the use of imported seed tubers from the Netherlands. The Nicaraguan farmers supported TPS-technology. That was until the Dutch government decided to "help" them with an interest-free roll-over credit for the purchase of Dutch seed tubers, which basically meant seed potatoes were free. In optimizing their short-term profits, the farmers turned away from TPS technology (Pallais, 1997). That behavior is then explained by the Dutch seed exporting industry as "proof" that TPS technology does not work. Such evidence helps to protect the status quo, and thereby the long term profits of the Dutch seed exporting sector.

Similar resistance can be found in the attitude of the distributors of agricultural supplies, for whom the income is a percentage of the seed that they sell. Since the demand for potato seed (clonal or botanical) is limited by the consumer demand for potatoes, they are unable to increase their profits by growth in the total market. Increasing their market share is difficult in a competitive market. Thus when the seed becomes significantly cheaper, their total income from seed sales can only decline.

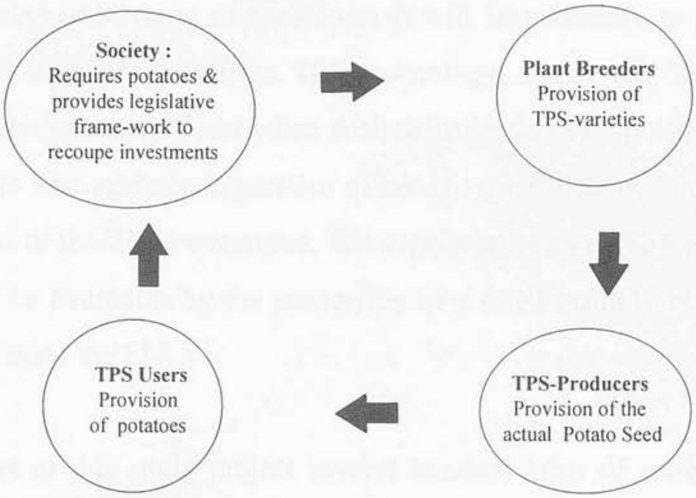
Only if a distributor can obtain exclusive rights to TPS for his regional area, does he stand a chance of maintaining his level of income. Without that he would only receive the same profit-margin from a less valuable market.

It appears unlikely that TPS technology can establish itself in the EU potato industry, or anywhere else, without the explicit support of some significant players of either the potato industry or the vegetable seed industry. Players who have the resources and stamina to overcome the resistance against change. Such support may not be easily found, since these two industries are not very well connected with each other (Gaasbeek et al, 1994). This makes the vegetable companies aversive to taking risks in the potato industry, and the potato companies averse to taking risk in the vegetable industry. To achieve success with TPS, one will have to operate in both industries .

9.5 Priorities for further research

The results from this study indicate that economic benefits may be expected from the use of TPS technology in the EU, and thus that further research in how to realize these benefits is warranted. The setting of research priorities for the advancement of TPS technology is not an easy task, since there are several critical links between the plant breeders, producers of TPS, users of TPS and the society that ultimately consumes the potatoes and provides the legislative system for all others to recoup their investments. These have been illustrated in Figure. 9.1.

Figure. 9.1. Linkages between stake holders in the EU potato industry



The uptake of TPS technology (and any technology for the provision of potato planting material) can easily end up in a vicious circle where everyone waits for someone else to start the process. Any form of applied research should therefore try to break this deadlock.

Research on the legislative frame-work in which TPS technology could operate is not very urgent until there is a demonstrated demand for it from both producers and consumers. Research on the breeding of better TPS varieties is certainly useful, but not extremely urgent since commercially acceptable varieties can be obtained from the USA. Research in optimizing the way and location of producing TPS is less urgent as well, since it appears from the modeling results (Chapter 8) that the technology can generate benefits even when the purchase/production price is higher than the one in the USA.

The bottleneck for the EU situation appears to be the lack of knowledge about the consumers' acceptance of the potatoes that are grown from TPS. Whether or not the consumer is willing to eat and buy these potatoes, will determine whether the growers of TPS-varieties will have a market for their products.

To test the market acceptance of consumers it will be necessary to produce a few hundred kilo of ware potatoes from TPS technology, which will then have to be tested by consumer panels. If and when such tests prove to be positive, subsequent research into the best agronomic practice of how to grow potatoes from TPS in the different regions of the EU is warranted. The supply problem of TPS for such a form of research can be overcome by the production of a small quantity of TPS from the USA-varieties inside the EU.

As a by-product of this study project several hundred kilos of ware potatoes will become available in the UK from the 1997 and 1998 potato production season, (see Chapter 4). Research on the consumer response to these samples will indicate more clearly where the potential of TPS technology in the EU for the next decade lies. The outcome of such research would then determine the need for further research into (i) potato growing from botanical potato seed; (ii) the breeding of TPS varieties;, and (iii) the production of botanical potato seed.

As long as there is uncertainty about the willingness of the consumer to eat the potatoes that have been grown with the use of TPS technology, its advancement both within the EU and elsewhere will be hampered.

9.6 Conclusions

This study explored the potential economic and agricultural impact of the use of TPS technology by the potato industry of the European Union. TPS technology was defined as a form of seed (tuber) potato production, based on of the direct seeding of True (i.e. botanical) Potato Seed, and the use of TPS varieties that are commercially available in the USA.

Results from a large mathematical simulation model of the EU potato industry indicate that substantial economic and agricultural benefits can be expected from the use of TPS technology, when applied[1] within the European Union. Under these circumstances the use of TPS technology would:

i Improve the gross margin of the industry as a whole by 130 million ECU per year.

ii Reduce the land needed for the cultivation of potatoes by 70,000 hectares.

iii Virtually eliminate the use of uncertified home-saved seed potatoes.

iv Increase the national average yields of ware, early and starch potatoes because of the increased use of certified seed.

v Allow for an increase of more than 9 % (11,000 ha) in the certified seed (potato) area.

Sensitivity analysis proved that the total impact of the technology is strongly and positively related to the seed tuber yields that are achieved from the direct seeding of TPS. To a lesser extend this also holds true for the costs of cultivating TPS. The benefits of the technology are negatively related to the price of the actual TPS, but the influence of large variations in TPS price was relatively small on the overall benefits of the technology. The benefits of the technology are highly dependent upon the acceptance of the TPS-varieties by the consumers of the EU. In the optimal situation close to 40 % of EU potato production would be done with TPS varieties. When consumer acceptance of the TPS varieties is limited to 0 % the IGM is zero. When the level of acceptance rises from 0 % to 20 %, the corresponding IGM rises very quickly to 96 % of the maximum achievable IGM value. When the acceptance level rises above 20 % the corresponding IGM only rises slightly. The rise in IGM values levels out when the acceptance level rises to more than 40 %.

The EU starch industry and the four southernmost EU members (Portugal, Spain, Italy and Greece) would most likely be the ones to switch to TPS technology the soonest. The main barriers for a swift uptake of TPS-technology within the EU are,

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[1] Assuming that the seed tuber yield (18 t/ha), cost of cultivation (4800 ECU/ha) and TPS purchase

the import ban on TPS from non-EU countries, the slow acceptance of new potato varieties, the unfamiliarity with the practice of direct seeding botanical potato seeds and the institutional resistance within the potato industry. To a certain extend it can thus be said that, "*the progress and application of TPS technology may lie in the hands of politicians, rather than scientists*." (Almekinders, Chilvers and Renia, 1996).

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price (2460 ECU/kg) are the same as for the situation of TPS use in the USA.

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APPENDICES

A.1	License to study the economic impact of TPS technology.
A.2	Description of five USA-bred potato hybrid (TPS) varieties.
A.3	License to import true potato seed from Chile.
A.4	Results of the TPS growing trials at SASA.
A.5	EU Plant Health Passport for tubers derived from imported TPS.
A.6	Summery of EU Potato data for 1991.
A.7	Distance and cost of road transport between countries of the EU.
A.8*	LP-model for the EU Potato Industry.
A.9*	Model outputs for selected scenarios of technology uptake.
A.10	Publications by the Ph.D.-candidate during the prescribed study period.

* Supplied on disk

A.1

LICENCE NO. PH/36/1995

SCOTTISH OFFICE AGRICULTURE AND FISHERIES DEPARTMENT
PLANT HEALTH ACT 1967
PLANT HEALTH (GREAT BRITAIN) ORDER 1993

The Secretary of State for Scotland by virtue of the provisions of Article 30 of the Plant Health (Great Britain) Order 1993 hereby authorises Professor J B Dent (Hans M Renia), Rural Resource Management Department, Scottish Agriculture College, West Mains Road, Edinburgh, EH9 3JG (hereinafter called "The Licensee") to retain 30gms of true potato seeds acquired on a visit to TPS Product Company in California, USA with the intention to study the potential benefits of TPS technology in Scotland.

This licence is subject to all other provisions of the Order and the following conditions.

1. The licensee shall take all precautions necessary to ensure that the true potato seeds kept under the authority of this licence are not distributed (except for destruction).

2. The licensee shall ensure that the true potato seeds are kept in a sealed glass container at all times during the currency of this licence, clearly labelled with licence number and handled by the licensee only.

3. The labelled sealed glass container shall also bear a warning. "The enclosed seeds should not be removed from this container" by order of SOAFD (licensee, Hans M Rennie).

4. No true potato seeds shall be removed from the above given address except with the written permission from the Plant Health Section, Scottish Agricultural Science Agency, East Craigs, Edinburgh, EH12 8NJ, telephone no. (0131) 244 8863, and they shall not be planted.

5. The licensee shall permit an authorised officer of the Scottish Agricultural Science Agency to inspect the conditions under which the true potato seeds are kept and handled.

6. At the expiry of this licence the true potato seeds shall be destroyed by autoclaving prior to disposal and the Scottish Agricultural Science Agency informed.

7. Acknowledgement of the authority of this licence for holding the true potato seeds shall be made in any publication concerning them.

8. This licence unless previously revoked shall remain in force up to and including the thirty-first day of December, Nineteen hundred and ninety-five.

THE SCOTTISH OFFICE AGRICULTURE AND FISHERIES DEPARTMENT
SCOTTISH AGRICULTURAL SCIENCE AGENCY

Dated the 21 day of April
nineteen hundred and ninety-five

Scottish Agricultural Science Agency,
East Craigs, Edinburgh, EH12 8NJ

Jane M Chard.
....
For and on behalf of the
Secretary of State for Scotland
Scottish Office Agriculture and
Fisheries Department

A2

TPS PRODUCTS COMPANY

™ Subsidiary of ESCAgenetics Corporation

DESCRIPTION

OF

PROPRIETARY POTATO HYBRIDS

30 Branston Road • San Carlos, CA 94070-3305, U.S.A. • Tel. (415) 595-5335 • Fax (415) 595-4332

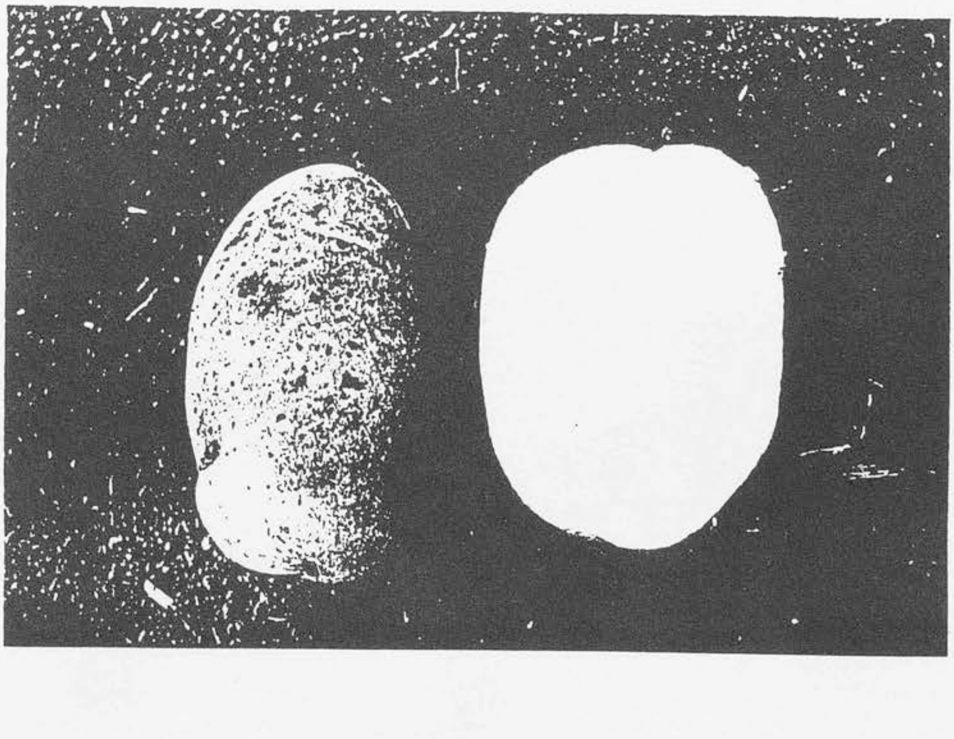
88.EX.2

TPS PRODUCTS COMPANY

Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Round-oval, blocky and slightly flat; medium to large; of good uniform shape and shallow eyes; smooth white skin; cream/white flesh.
Yield	-	Good to very good, broad range adaptability over years and environments; size grade distribution good with highest proportion of yield in 40mm to 80mm size grade; occasional growth crack with few outgrades.
Dry matter content	-	Medium to high.
Consumer quality	-	Fairly firm texture on boiling; free from enzymatic browning and after cooking blackening; excellent fry color; highly recommended for fries and chips; practically no internal defects such as hollow heart, internal brown spot or net necrosis; occasionally (up to 3%) purplish spots in the flesh may appear if improper cultural practices occur.



830 Bransten Road • San Carlos, CA 94070-3305, U.S.A. • Tel. (415) 595-5335 • Fax (415) 595-4332

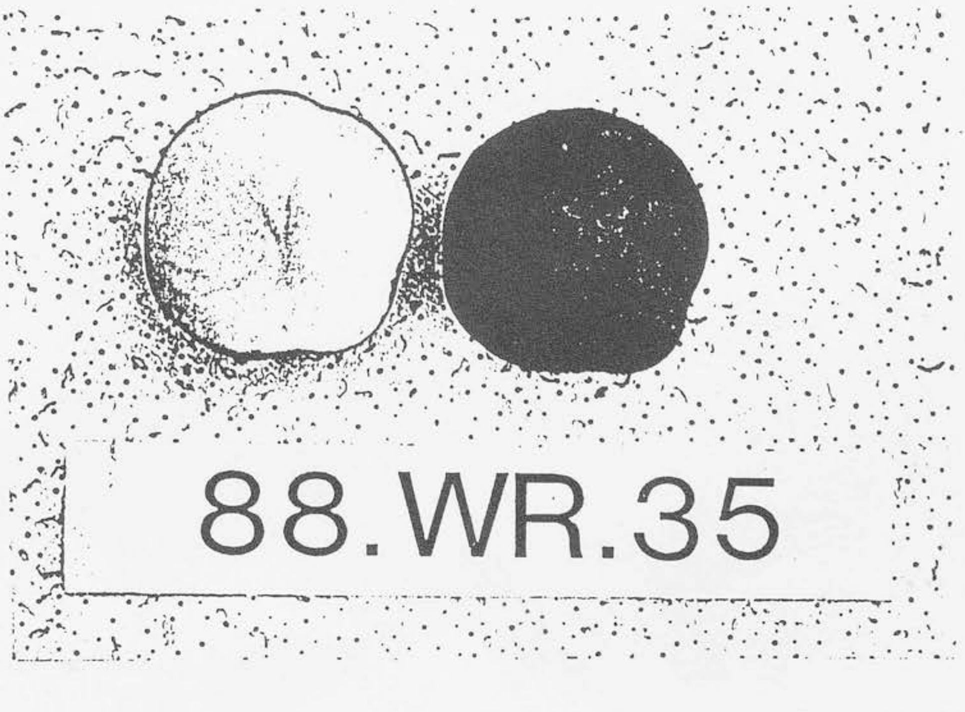
8 8 . W R . 3 5

TPS PRODUCTS COMPANY

™ Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Extremely uniform round; numerous and of medium size, smooth white skin with shallow eyes; flesh cream/white.
Yield	-	Good; high proportion of tubers in grade of 40 to 80 mm size; tendency for tuber insertion at stolon end; occasional growth cracks.
Dry matter content	-	Medium.
Consumer quality	-	Slight sloughing of tubers on boiling; free from enzymatic browning and after cooking blackening; fry color good; practically no internal defects such as internal brown spot, net necrosis and hollow heart.



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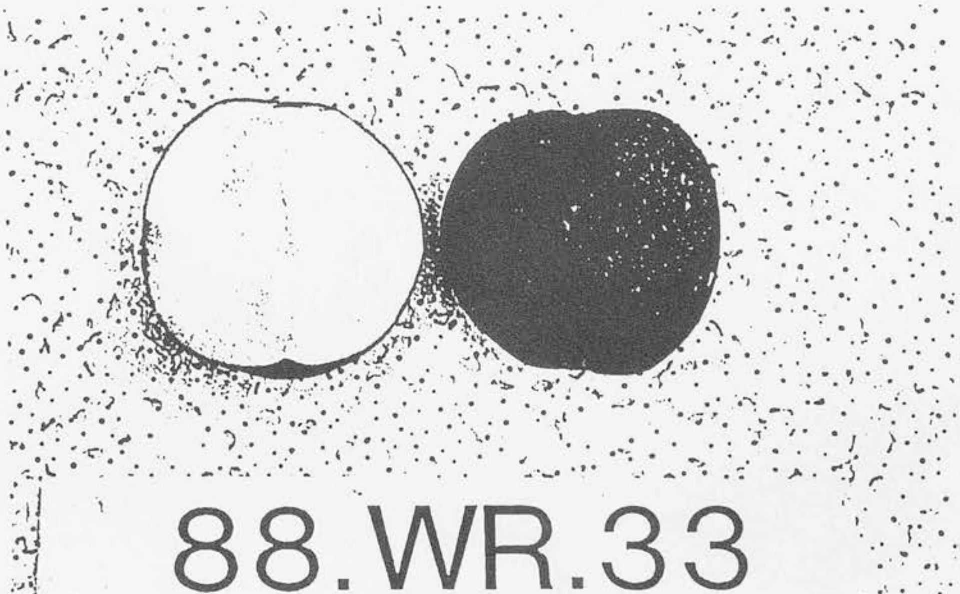
8 8 . W R . 3 3

TPS PRODUCTS COMPANY

™ Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Highly uniform round; visual appearance is very attractive; medium to large size, with bigger proportion in the medium category; smooth white skin with shallow eyes; flesh white.
Yield	-	Good. Excellent yield also from TPS. Large number of tubers.
Dry matter content	-	Medium to high.
Consumer quality	-	Less firm texture on boiling; completely free from enzymatic browning and after cooking blackening; excellent quality of chips. No internal defects.



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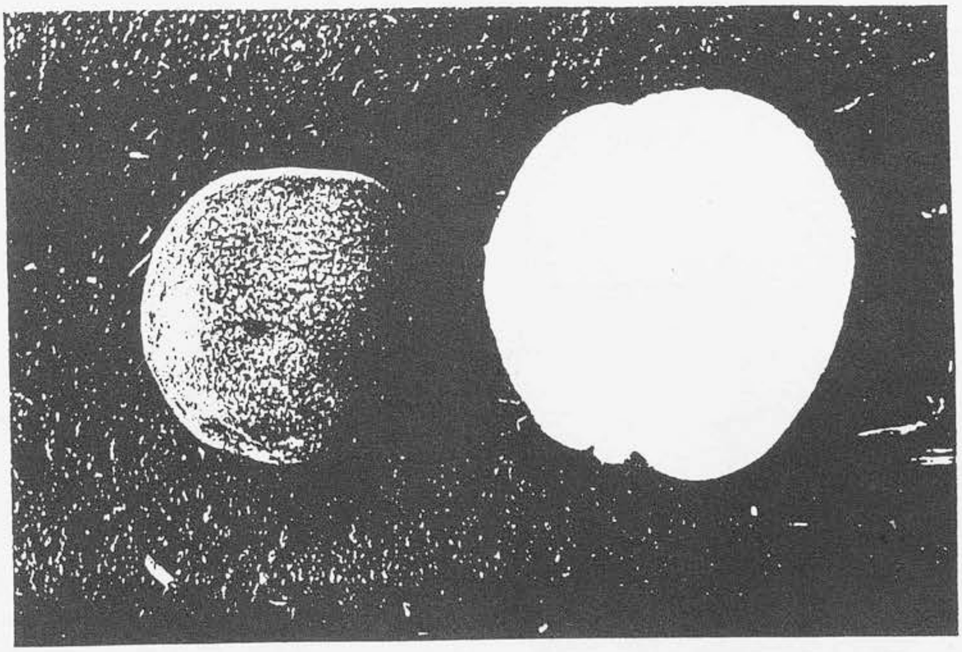
88.WR.49

TPS PRODUCTS COMPANY

™ Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Uniformly round/oval; large; good uniform shape and medium deep eyes; smooth white skin and cream/white flesh.
Yield	-	Good to very good; size grade distribution very good, large proportion of tubers in large size grades; slight tendency for persistent stolons; occasional growth crack and very few secondary growth defects.
Dry matter content	-	Medium to high.
Consumer quality	-	Fairly firm texture on boiling; relatively free from enzymatic browning and after cooking blackening; good fry color; occasional hollow heart but very few other internal defects such as internal necrosis and internal brown spot.

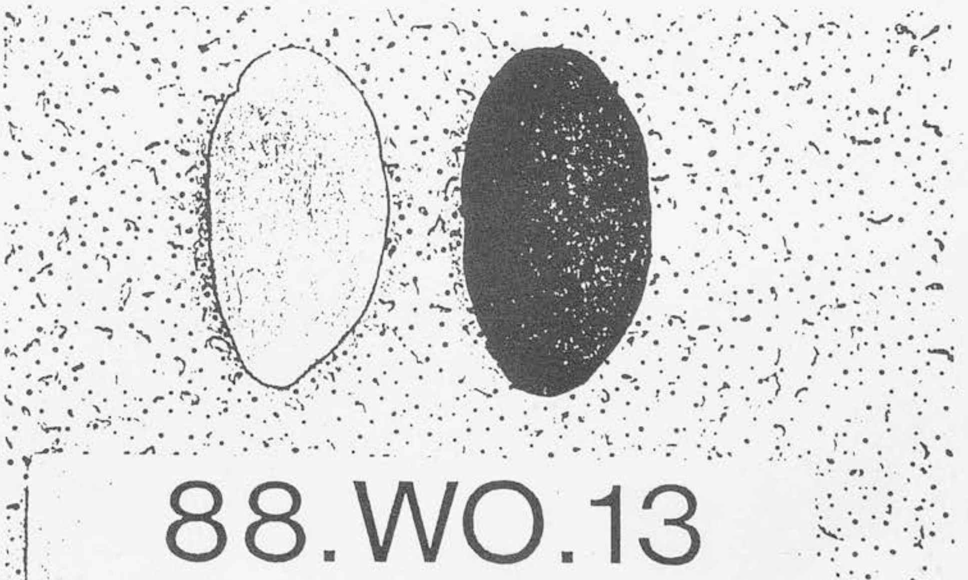


88 . WO . 13

TPS PRODUCTS COMPANY
™ Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Long oval; smooth white skin with shallow eyes; flesh white. Visual appearance is very attractive; medium to large; few knobby tubers can be found.
Yield	-	Good, broad range adaptability over years and environments; tuber size distribution can result in a certain proportion of small tubers if under inappropriate growing conditions.
Dry matter content	-	Medium.
Consumer quality	-	Fairly firm texture on boiling; relatively free from enzymatic browning and after cooking blackening; few internal brown spot cases under unfavorable environmental conditions but no other problems of internal quality of tubers.



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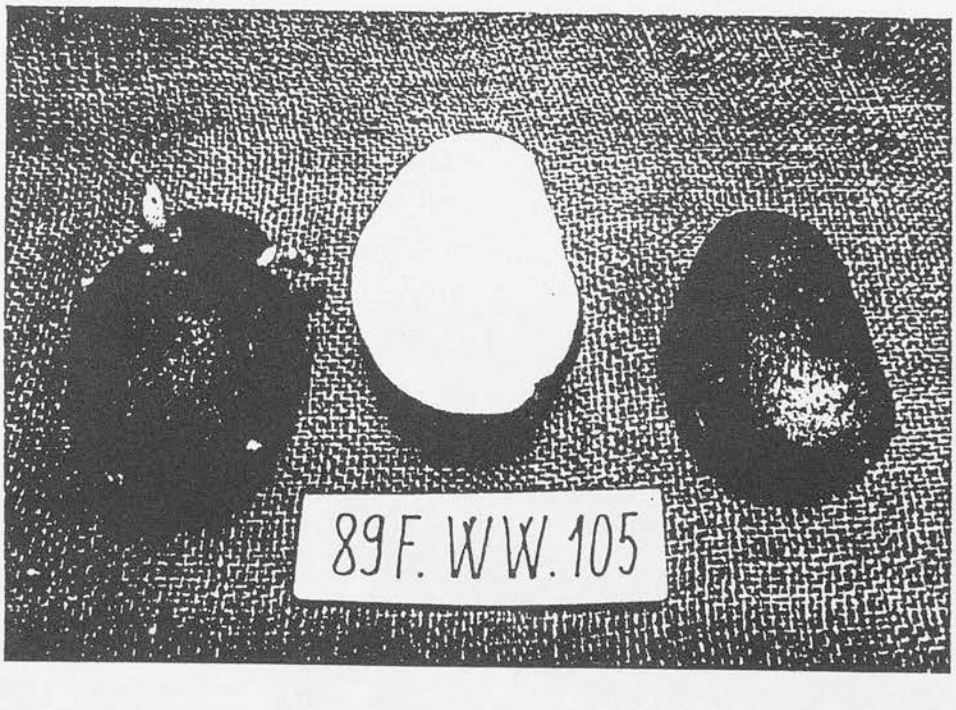
TPS PRODUCTS COMPANY
™ Subsidiary of ESCAgenetics Corporation

Tuber characteristics

Tubers	-	Flat oval; fairly large, very uniform and attractive tubers; smooth white skin with shallow eyes; flesh cream/white.
Yield	-	Good; size grade distribution very good, large proportion of tubers in large size grades; uniform tubers; early tuberization.
Dry matter content	-	Medium to high.
Consumer quality	-	Fairly firm texture on boiling; relatively free from enzymatic browning and after cooking blackening; fry color good; few internal defects; occasionally purplish spots can be detected in flesh in up to 3% tubers, if improper cultural practices occur.



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A3

LICENCE NO. **PH/BQ/1995/14**

SCOTTISH OFFICE AGRICULTURE AND FISHERIES DEPARTMENT
PLANT HEALTH ACT 1967
PLANT HEALTH (GREAT BRITAIN) ORDER 1993

The Secretary of State for Scotland by virtue of Article 30 of the Plant Health (Great Britain) Order 1993 hereby authorises :

Hans Renia, SAC, Kings Buildings, West Mains Road, Edinburgh, EH9 3JG

to import up to **300 true potato seeds** (weight of seed within brackets after line name) of each of the following *Solanum* species, accessions or potato cultivars :

88.EX.2	**(0.19 grams)**	**89.FWW.105**	**(0.18 grams)**
89.FWW.102	**(0.18 grams)**	**88.WO.13**	**(0.20 grams)**
88.WR.32	**(0.19 grams)**	**88.WR.33**	**(0.23 grams)**
88.WR.35	**(0.17 grams)**	**88.WR.49**	**(0.21 grams)**
89.FWW.3	**(0.23 grams)**		

from **Agrocomercial, ESCA Chile LTDA, Manuel Antonio Matta, 1125 Osorno, Chile**

The plants shall be despatched directly to:

The Plant Pathologist (Breeders' Quarantine Unit),
Scottish Agricultural Science Agency,
Edinburgh EH12 8NJ,
UK

accompanied by this licence. The conditions which apply to this licence are shown overleaf.

The licence expires 31/12/95 unless previously revoked.

dated: 02/11/95

THE SCOTTISH OFFICE AGRICULTURE AND FISHERIES DEPARTMENT
SCOTTISH AGRICULTURAL SCIENCE AGENCY

Scottish Agricultural Science Agency,
East Craigs, Edinburgh, EH12 8NJ, UK

For and on behalf of the Secretary of State for Scotland, Scottish Office Agriculture and Fisheries Department.

APPENDIX 4 :

RESULTS FROM TPS GROWING TRIALS IN THE UK

Summery of results on 1996 tps trials

				Number of tubers per size category (in mm)						Weight
	number of	number of		0-10	10 - 20	20 - 30	30 - 40	40 - 50	50 +	(gramms)
	plants	tubers								
88.EX.2	62	725		166	153	174	136	57	39	5,433
88.WR.32	52	503		108	132	115	94	44	10	4,386
88.WR.33	61	635		89	232	165	95	47	7	5,474
88.WR.35	85	610		54	169	155	149	72	11	8,030
88.WR.49	25	278		42	97	74	52	13	0	2,142
88.WO.13	32	506		123	137	132	80	30	4	2,301
89.FWW.3	55	599		115	220	163	75	23	3	4,902
89FWW.1	44	460		67	133	123	93	32	12	4,756
89.FWW.1	53	798		185	214	178	144	67	10	5,125
	469	5114		949	1487	1479	918	385	96	42,550
				Percentage of tubers per size category (in mm)						
				0-10	10 - 20	20 - 30	30 - 40	40 - 50	50 +	
88.EX.2				23	21	24	19	8	5	
88.WR.32				21	26	23	19	9	2	
88.WR.33				14	37	26	15	7	1	
88.WR.35				9	28	25	24	12	2	
88.WR.49				15	35	27	19	5	0	
88.WO.13				24	27	26	16	6	1	
89.FWW.3				19	37	27	13	4	1	
89FWW.102				15	29	27	20	7	3	
89.FWW.105				18	30	25	18	7	2	
Total				18	30	25	18	7	2	
		Average number of tubers per plant								av. weight
		> 0 mm		0-10	10 - 20	20 - 30	30 - 40	40 - 50	50 +	
88.EX.2		11.7		2.7	2.5	2.8	2.2	0.9	0.6	87.6
88.WR.32		9.7		2.1	2.5	2.2	1.8	0.8	0.2	84.4
88.WR.33		10.4		1.5	3.8	2.7	1.6	0.8	0.1	89.7
88.WR.35		7.2		0.6	2	1.8	1.8	0.8	0.1	94.5
88.WR.49		11.1		1.7	3.9	3	2.1	0.5	0	85.7
88.WO.13		15.8		3.8	4.3	4.1	2.5	0.9	0.1	71.9
89.FWW.3		10.9		2.1	4	3	1.4	0.4	0.1	89.1
89FWW.102		10.5		1.5	3	2.8	2.1	0.7	0.3	108.1
89.FWW.105		15.1		3.5	4	3.4	2.7	1.3	0.2	96.7
Total		11.4		2.2	3.3	2.9	2	0.8	0.2	89.7

TPS Variety: 88.EX.2				seeded Dec 1995		harvested 5 August 1996				
Pot	number of tubers		Size distribution (in mm) 0-10	10-20	20-30	30-40	40-50	50 +		Weight (gramms)
2	7			2		3	2			42.2
3	11		2	2	2	3	2			128.2
4	16			5	10	1				113.6
7	19		7	2	4	4		2		130.7
8	11		1		4	2	2	2		141.6
9	9		1	2	1	5				78.8
10	7		6		1					8.4
11	11			2	1	1	5	2		146.5
12	13		3	2	4	4				57.3
13	9			4		2		3		98.5
14	8		1	3	1	2		1		58.7
16	5					3	2			66.9
17	24			8	7	9				111.3
18	16		7	2	6	1				57.4
19	10		3	2	1	1	3			86.4
20	7			3	3	1				36.7
21	4							4		118.3
23	6			2	2	2				71.8
25	11		1	2	5	1		2		146.3
26	11		3	1		4	3			137.3
27	12		1	1	3	3	4			106.0
28	17		4	3	4	6				96.0
29	21		8	8	5					55.7
30	17		6	1	3	5	1	1		128.7
31	7		1		2	3	1			94.2
32	6				3	2	1			34.8
33	15		7	2	4	2				70.6
33	7		1		1	5				62.7
34	7			1	4	2				52.7
35	25		9	4	8	3	1			136.8
36	17		4	4	6	1	2			75.4
37	8			5	2		1			52.0
40	20		9	1	3	4	2	1		113.8
41	8			3	1	4				82.0
42	5			1	2			2		78.4
43	8		3		3	1		1		38.8
44	8		1	3	2		2			84.5
45	5			1	2	2				58.7
46	10		2	4	4					63.0
48	15		1	6	3	2	2	1		134.5
49	15		4	3	4	1		3		167.3
50	10		5		2	3				31.3
51	10		5	2	2			1		46.2
53	12			5		5	1	1		156.7
54	11			5		2	3	1		103.1
56	11		2	3	2	2	1	1		131.2
57	8			2	1	3	1	1		89.9
60	7		2	2	3					29.9
62	17		3	2	2	5	4	1		203.0
63	14		1	5	5	1	1	1		90.2
64	4		1	3						11.6
65	14		4	4	2		1	3		113.8
66	20		9	4	5	2				79.6
67	15		9	3	3					19.7
68	9		1	3	3		1	1		80.4
71	9		2	0	0	2	3	2		132.2
72	5		1	1	2	1				34.1
73	11		2		5	3		1		88.8
75	13		1	1	5	3	3			94.9
76	12		2	4	2	3	1			92.6
79	17		4	4	4	5				72.3
80	28		16	5	5	1	1			108.5
Total										
62	725		166	153	174	136	57	39		5433.4
			23%	21%	24%	19%	8%	5%		
Average	11.7		2.7	2.5	2.8	2.2	0.9	0.6		87.6

ESCA-code 88.WR.32				seeded Dec 1995		harvested 5 August 1996				
pot	number of tubers		Size distribution (in mm) 0-10	10-20	20-30	30-40	40-50	50 +		Weight (gramms)
1	9			2	3	1	2	1		111.6
2	11		1	3	4	3				106.9
4	6		1	2	2	1				38.9
5	7		1		2	3		1		89.4
6	22		7	10	5					80.8
7	6		1	1	3		1			91.3
8	3			1				2		76.9
10	16		7	2	2	4		1		101.1
11	8		1	1	3	3				58.5
12	6		3			2	1			78.2
13	8		1	1	2	4				91.8
14	17		9	2	4	2				71.7
14	11		3	4	1		3			101.5
15	14		2	3	4	4	1			102.3
18	11		3	1	2	5				113.5
22	7				1		6			137.07
23	5		2	1	2					13.8
24	10		3	1	5	1				80.1
25	7			2	3	1	1			99.2
26	15		2	6	1	6				89.5
27	8			1	1	5	1			97.8
28	7		2	2			2	1		121.7
30	11		1	3	3	4				107.9
31	6			2	2	2				37.9
32	10		3	3	3		1			58.9
33	7			1	3	2	1			61.7
34	6				3	1	1	1		97.7
35	25		5	13	5	1	1			107.4
37	5			1			3	1		120.2
38	5		1		2	2				103.3
39	2		1	1						3.2
41	7		1	1	2	3				80.5
42	11		3	2	1	3	2			104
43	24		13	10	1					50.3
45	10			1	3	4	2			119.8
46	4		1		1	1	1			62.4
47	5			1			2	2		138
48	9		2	4	2	1				71.7
49	10		3	6		1				53.6
50	6			1	2		3			121
51	3		1	1	1					7.5
52	16		4	5	3	3	1			76.9
53	12		5	4	1	2				66.8
54	20		9	6	3	2				74.7
56	10			2	4	3	1			124.8
57	6			1	1	1	3			113.1
59	15		1	4	4	5	1			117.5
60	9		1	3	3	2				59.5
62	9		2		4	1	2			77.1
63	15		2	7	6	0	0			91.6
63	8			3	2	3				38.5
64	3					2	1			85.2
Total										
52	503.0		108.0	132.0	115.0	94.0	44.0	10.0		4386.3
			21%	26%	23%	19%	9%	2%		
Average	9.7		2.1	2.5	2.2	1.8	0.8	0.2		84.4

TPS-variety 88.WR.33			seeded Dec 1995			harvested 5 August 1996				
Pot	number of		Size distribution (in mm)							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
1	10			4	4		2			106.9
2	8			2	5	1				93.3
3	4			1		3				80.5
4	14		5	3	2	3		1		81.8
5	8		1	2	2	1	1	1		121.5
6	15		3	6	2	2	1	1		90.2
7	10		4	2	2	1	1			88.8
8	6		1		2	1	2			91.0
9	23		10	6	3	4				104.7
10	10		1	1	2	6				114.2
11	6		1	2	2		1			64.2
12	8			2	1	4	1			111.0
13	11		3	3	3	1	1			72.3
14	7			4		1	2			97.9
15	12		5	3	2		1	1		109.2
17	4			1	2	1				59.9
18	11			7	3	1				71.6
20	14			6	5	2	1			120.5
21	13		3	9	1					47.3
22	7				2	4	1			90.4
24	11		1	6	3	1				47.9
26	5			1	1		2	1		109.7
27	25		4	15	5	1				105.9
28	18		1	10	4	2	1			104.2
29	12		4	4	2	2				80.7
30	8		2	2	2	2				65.8
32	12		3	5	3	1				80.3
33	9			4	2	3				80.4
34	14		7	4	1	2				72.5
36	16		3	7	4	1	1			120.5
37	14			4	4	6				107.9
38	12			7	3		2			106.3
39	12		1	6	5					52.2
40	11			5	3	1	2			118.6
41	10			6	1	2	1			50.3
42	8			2	4	1	1			102.6
43	10			2	2	3	3			120.2
44	10			5	3	1		1		82.9
45	7		1	4		1	1			78.3
46	16		0	4	8	4	0	0		104.4
47	10			2	4	3	1			108.9
48	13		3	4	4	1	1			107.9
49	8			2	3	1	2			119.1
50	13			5	6		2			108.9
52	10			6			4			96.2
53	4				2	1	1			103.7
55	10		1	3	2	3	1			128.5
56	6		1	2	3					40.2
57	12		2	4	4	1	1			103.2
58	5		1	2	2					23.4
59	8		2	2	3		1			60.2
60	10		3	3	2	2				69.3
61	5			2	2			1		90.1
63	20		10	4	5	1				98.5
64	12			3	5	3	1			110.8
65	13		1	7	5					57.6
66	8			2	4	1	1			98.1
67	6			2	2	1	1			85.8
68	6			3		2	1			99.8
69	7		1	2	1	3				76.8
no-numb	8			5	1	2				78.4
Total										
61	635		89	232	165	95	47	7		5474.2
			14%	37%	26%	15%	7%	1%		
Average	10.4		1.5	3.8	2.7	1.6	0.8	0.1		89.7

TPS-variety 88.WR.35				seeded dec. 1995		harvested 5 Agust 1996				
Pot	number of		Size distribution (in mm)							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
1	4				1	1	1	1		151.3
2	9		2	2	3	2				63.2
3	10			3	3	3	1			123.3
4	11			8	3					28.2
5	3				1	1	1			79.4
6	11		2	1	6	1	1			80.3
9	13		3	3	2	4	1			127.0
11	8			3	1	3	1			110.8
12	9		1	4	4					81.7
13	9			3	1	5				104.9
15	4					4				80.7
16	6			1		4	1			91.0
17	14			9	2	3				115.6
18	6			3	2		1			74.7
19	5			1	3		1			65.0
20	11		2	3	5	1				90.1
21	8			3	3	1	1			98.0
22	4		2			2				38.6
23	9		2	3	1	2	1			93.8
24	6		2	3	1					14.9
25	7			1	2	1	3			118.8
26	2			1			1			40.9
27	8			3	2	1	2			119.6
28	11		1	4	4	2				88.6
29	5				2	1	2			85.4
30	7		3	1	1	1	1			92.2
31	6		2		1	2	1			80.8
32	4		1		1	2				65.2
33	17		6	8	3					69.6
34	6			1	3	2				67.3
35	6			2	2	1	1			93.4
36	8		1	1	3	3				134.7
37	12		2	3	3	4				82.4
38	4			1			3			75.5
40	8			3	1	2	2			116.6
41	3			1		2				101.2
42	6			1	1	4				88.4
43	6			2	3	1				69.3
44	4				2	1	1			64.5
45	7		1	1	1		4			99.4
46	7			1	3	2	1			80.3
47	8			4	3	1				73.8
48	5			1	1	1	2			87.4
49	6				3	3				113.7
50	4		1	1	1	1				38.9
51	6		1		3	1	1			89.8
53	4		1	2	1					36.0
54-A	4				1	2	1			110.1
54-B	10			5	3	2				108.3
57	3					1	1	1		106.5
58	12		1	5	4	2				115.3
59	8		2		1	4	1			116.0
60	6		1	2	1	1	1			80.2
61	6			3		1	2			112.3
62	8		2	1	2	2	1			84.4
63	5			1	1	3				90.4
64	7		1	1	1	4				99.5
65	5			1		2	2			115.0
66	7			1	2	3	1			115.5
67	9			4	2	1	2			85.7
68	5			2	1	1	1			90.5
69	7		1	3	1	1	1			117.9
70	3			2		1				20.4
72	9			4	3	2				84.2
73	6			3	1			2		112.1
75	6			2	2	2				71.5
76	8			4		1	3			106.4
77	7		1	1	1	4				111.2
78	2					1		1		89.6
78	6		1	2	2		1			94.6
79	6			2	1		3			129.3
80	13		2	4	3	2	2			104.2
81	9		1	2	2	3		1		106.6
83	2		0	0	0	0	1	1		95.6
85	7		1	1	1	4				89.1
86	9			4	2	2	1			80.7
88	5				1	4				87.5
89	4			2	1	1				84.1
90	5			1	2		1	1		130.6
91	8			1		4	1	2		147.4
92	5		1	1	3					108.1
93	11		1	2	2	5	1			103.4
95	7				2	1	3	1		142.4
98	9		1	1	5		2			113.0
99	13		1	3	6	3				79.9
Total										
85	599		54	167	152	146	69	11		7825.7
			9%	28%	25%	24%	12%	2%		
Average	7.0		0.6	2.0	1.8	1.7	0.8	0.1		92.1

TPS-variety 88.WR.49			seeded Dec. 1995			harvested 19 September 1996				
Pot	number of		Size distribution (in mm)							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
4	7		1	1	4		1			71.3
7	1			1						0.8
9	3			3						6.5
10	9		1	3	2	2	1	0		59.3
16	14		1	3	4	6				150.7
17	10		1	3	2	4				112.6
22	21		2	12	7					96.7
26	11		1	3	3	3	1			84.6
27	21		4	2	8	4	3			164.1
35	11			2	3	4	2			129.6
38	17		6	4	3	4				115.9
42	20		6	9	5					57.4
43	7			4	3					33.3
47	10		2	4	2	2				101.8
48	15		4	4	6	1				65.0
49	11		4	4		2	1			94.9
50	6				1	5				72.9
52	12		1	4	4	1	2			151.6
53	12		1	4	2	4	1			129.6
54	10		1	3	3	3				106.7
55	11			6	4		1			101.3
58	2		1	1						34.4
59	19		3	9	4	3				109.8
61	13			5	4	4				88.9
62	5		2	3						2.3
Total										
25	278		42	97	74	52	13	0		2142.0
			15%	35%	27%	19%	5%	0%		
Average	11.12		1.68	3.88	2.96	2.08	0.52	0		85.7

TPS-variety 88.WO.13			seeded Dec 1995			harvested 5 August 1996				
Pot	number of		Size distribution (in mm)							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
1	6			3	2	1				22.3
2	22		4	10	7		1			78.2
4	10			2	3	2	3			123.3
5	29		13	7	4	5				85.4
6	13		3	1		5	4			91.8
12	14		5	3	3	3				43.6
13	17		10	4	3					46.5
14	22		7	5	6	4				72.2
16	22		2	4	4	6	6			140.3
18	14		4	4	3	2	1			44.4
19	17		6	2	5	4				70.0
21	13		1	4	4	3		1		123.0
22	34		21	5	2	5	1			81.6
23	20		2	7	10	1				69.0
26	19		5	3	5	3	2	1		117.8
27	10		2	1	3	2	2			74.2
28	2					2				25.0
30	20			6	9	4	1			167.8
33	4				3	1				32.3
34	9		6		3					10.2
36	6		1	2	3					11.1
37	20		9	1	5	4	1			62.9
38	7		1	6						8.9
42	12			5	5		2			40.2
43	10			5	2	3				34.7
44	4		2	1	1					6.3
45	31		5	15	6	4	1			128.5
46	11			3	6		2			52.1
51	15		3	3	4	4		1		108.3
52	35		8	13	9	5				126.2
54	11		1	4	6					43.0
56	27		2	8	6	7	3	1		159.8
Total										
32	506		123	137	132	80	30	4		2300.9
			24%	27%	26%	16%	6%	1%		
Average	15.8		3.8	4.3	4.1	2.5	0.9	0.1		71.9

TPS-variety 89.FWW.3			seeded 20 december 1995			harvested 5 August 1996				
Pot	number of		Size distribution (in mm)							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
1	15		2	4	7	2				96.9
2	20		6	6	8					122.7
3	11		6		3	1	1			103.7
8	10		1	2	4	2	1			120.2
10	17		6	5	4	2				102.4
12	8			3	3	2				104.0
13	16		4	10		1	1			114.8
14	7			2	1	3	1			96.2
15	8		1		4	3				78.1
16	6			1	5					76.1
17	12			8	1	2	1			66.5
18	7		2		1	3	1			110.1
19	12		2	5	3	2				85.7
20	8		5		3					34.9
22	8			4	3		1			67.4
23	7		4	1	2					29.3
24	5		1	3	1					30.8
25	12			1	4	5	1	1		163.0
26	15			6	6	3				111.7
29	18		5	9	4					74.5
30	9		3	3	2	1				44.7
31	3			1			2			61.3
32	11		6	2	3					47.1
33	5				5					45.2
35	5			3	2					36.3
36	14		2	4	4	4				137.1
37	8			3	1	1	2	1		148.1
38	11		3	3	5					84.2
39	14		1	6	4	3				113.0
40	8		3	2	1	2				79.6
41	7			7						18.3
42	9		1	2	5		1			113.6
43	9		1	2	3	3				98.0
45	12		3	7	2					47.4
46	14		5	6	3					53.7
47	13			5	7		1			136.3
48	10		5	4	1					22.8
49	11			5	2	3		1		131.0
50	8			4		2	2			98.2
51	19		2	10	5	2				97.9
53	10			2	4	3	1			154.2
54	12		1	7	2	2				92.0
55	10		4	3	2		1			74.3
56	11		3	5	2		1			73.3
57	14		6	3	4	1				101.7
58	11		4	5	2					52.7
59	14			4	5	4	1			115.6
60	7		2	2	1	2				88.5
61	12		2	5	2	2	1	0		116.5
62	9			3	2	3	1			120.7
63	21		6	9	5	1				117.2
64	10		3	5	1	1				95.6
65	13			6	4	3				110.0
66	17		3	9	3	1	1			111.5
67	6		1	3	2					75.1
Total										
55	599		115	220	163	75	23	3		4901.7
			19%	37%	27%	13%	4%	1%		
Average	10.9		2.1	4.0	3.0	1.4	0.4	0.1		89.1

TPS-variety 89.FWW.102			seeded Dec 1995			harvested 5 August 1996				
Pot	number of		Size distribution							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
2	9			2	3	4				127.5
3	6			2	3		1			89.4
4	15		5	2	5	1	2			135.2
5	16		4	4	4	2	2			110.6
6	22		3	8	5	5	1			131.1
8	20		6	7	5	1	1			93.1
9	10		2	1	2	3	2			117.1
10	4			1		1	2			95.9
11	8			6	1		1			66.2
13	10		1	2	5	1	1			111.4
14	11		1	4	1	5				86.9
17	15		3	7	2	2	1			82.5
18	10		1	1	4	3		1		131.1
19	5		1	2		1		1		100.4
20	10			2	2	3	3			141.3
21	7			1	4	1	1			95.4
22	11		3	4	1	3				63.8
23	8		2	1	2	1	2			144.8
24	10		1	2	1	5		1		114.4
25	9		2	2	2	3				86.3
26	9		1	2	3	1	2			115.3
27	13		3	3	5		2			125.5
28	6			2	1	2		1		96.6
29	12		4	3		3	1	1		122.8
30	8		1		4	2		1		127.6
31	15		5	7	1	2				70.9
32	5				5					145.2
35	12		1	5	5	1				103.8
36	17			8	4	4	1			130.6
38	9		3		6					59.4
40	12		3		3	6				145.5
41	4				2	1		1		112.6
42	11			3	4	2	2			115.6
43	10			4	5	1				86.6
44	11		2	3	2	3	1			103.7
46	18		3	4	4	6	1			121.7
48	12		1	5	2	4				75.2
49	10		1	3	2	4				90.8
50	7			1	2	3		1		121.7
51	9		2	2	3		1	1		126.2
53	13		1	9	3					72.1
56	4			3				1		118.6
57	11		1	3	3	3	1			120.4
94	6			2	2			2		122.9
Total										
44	460		67	133	123	93	32	12		4755.7
			15%	29%	27%	20%	7%	3%		
Average	10.5		1.5	3.0	2.8	2.1	0.7	0.3		108.1

TPS-variety 89.FWW.105				seeded Dec 1995		harvested 5 August 1996				
Pot	number of		Size distribution							Weight
	tubers		0-10	10-20	20-30	30-40	40-50	50 +		(gramms)
2	15		1	3	4	4	2	1		122.5
3	14			5	3	6				108.4
4	3				1	1	1			72.6
5	16		1	4	3	2	6			109.8
6	23		1	12	6	4				125.4
7	17		2	2	4	7	2			104.1
8	16		1	6	5	4				89.9
9	13			4	3	5	1			138.5
10	11		1	1	1	2	5	1		111.4
11	20		6	4	5	2	2	1		128.9
12	14			2	4	6	2			103.6
13	13		5	1	1	3	3			112.3
15	15			5		7	3			141.3
16	9		6	3						9.3
17	19			4	5	7	2	1		160.9
18	10		1	1	3	5				122.8
19	23		12	1		4	6			138.0
20	16		1	5	3	2	4	1		159.7
21	16		5	2	5	4				92.8
22	16		3	4	5	4				151.4
23	10			3	2	3	2			116.6
25	7		3	2	1	1				27.7
26	20		5	8	4	3				130.7
26-b	10		4	4	2					19.3
27	12		2	4	3	2		1		100.4
28	26		9	8	6	3				46.5
31	12		1	5	4			2		80.3
33	15		5	3	2	3	2			141.2
35	8			1	1	3	3			87.3
36	18			5	12			1		125.0
38	16		2	7	6	0	0	1		108.6
40	10		3	1	4	2				118.2
41	12		5	4	3					20.1
42	23		7	11	2	2	1			77.8
44	11		6	2	3					37.5
45	13		6	1	3	3				63.9
46	12		1	5	3	3				58.7
47	17		2	6	8		1			103.2
48	6			2	2	2				46.6
49	5		1	1	1	1	1			60.4
50	22		10	4	3	4	1			98.3
51	25		9	8	4	4				88.1
52	16			7	4	3	2			106.0
53	7		1		5		1			49.0
54	21		5	5	5	3	3			182.6
55	10			3	2	1	4			103.9
56	12		2	7	3					83.5
57	13		5	4	3		1			92.2
58	24		12	4	3	5				69.8
58	14		1	7	3	3				97.4
59	6		2			1	3			89.4
60	13		2	3	4	4				98.7
61	53		28	10	6	6	3			93.3
Total										
53	798		185	214	178	144	67	10		5125.8
			23%	27%	22%	18%	8%	1%		
Average	15.1		3.5	4.0	3.4	2.7	1.3	0.2		96.7

A.5

Computer entry _______ Delivery Note 200

EEC PLANT PASSPORT UK/S/9999

The UK Potato Quarantine Unit, Scottish Agricultural Science Agency, East Craigs, Edinburgh, EH12 8NJ

To: *Hans Renia,*
Scottish Agricultural College,
Kings Buildings,
West Mains Road,
Edinburgh
EH9 3JG

Product: **Potato tubers (*Solanum* tuberosum)**	**Origin**	**Approximate number of tubers**
88.EX.2 (C1)	Chile	120
88.WR.32 (C2)	Chile	120
88.WR.33 (C3)	Chile	120
88.WR.35 (C4)	Chile	120
88.WR.49 (C5)	Chile	120
88.WO.13 (C7)	Chile	120
89.FWW.3 (C7)	Chile	120
89.FWW.102 (C8)	Chile	120
89.FWW.105 (C9)	Chile	120
		0

The seedlings/plants from which the tubers were derived were quarantine tested for PSTVd and seed-borne viruses in accordance with Commission Decision 80/862/EEC (as amended 91/22/EEC) and also potato yellowing virus. No pathogens were detected. No pests were observed during the growing cycle.

Quarantine tests : Tests for PSTVd were done using cDNA probe or return PAGE, viruses by ELISA and bioassay to *Chenopodium amaranticolor, C murale, C quinoa* and *Nicotiana bigelovii.* During the growing season plants were regularly inspected and those with atypical symptoms for the line subject to further investigation and scrapped as appropriate. The symptoms observed in the absence of a pathogen were thought to reflect the heterogeneous nature of true potato seed.

Your attention is drawn to the conditions in Licence PH/BQ/1995/14 which are attached to the passport.

Checked: C Jeffries Despatch: 26/03/1997 Method of transport: Collected

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Delivery Note 200

Please detach and return to : Dr C Jeffries, The UK Potato Quarantine Unit, Scottish Agricultural Science Agency, East Craigs, Edinburgh, EH12 8NJ. Telephone No. 0131 244 8868.

I acknowledge receipt of the above material:

Signature ______ Date 26/03/1997 Position Research Fellow

6 A SUMMERY OF EU POTATO DATA 1991

	EU-12	Germany	France	Italy	NL	Danmark	Belg-Lux	UK	Ireland	Spain	Portugal	Greece	Sources
Total area (1000 ha)	1,536	342	171	118	180	43	58	176	20	266	109	52	Eurostat 1995, Agricultural Statistical Yearbook 1995.
Total production (1000 t)	42,829	10,201	5,467	2,219	6,949	1,462	2,021	6,267	571	5,182	1,370	1,119	Eurostat 1995, Agricultural Statistical Yearbook 1995.
Average yield (t/ha)	28	29.83	31.97	18.81	38.61	34.00	34.84	35.61	28.55	19.48	12.57	21.52	production / area
Seed													
Seed area (certfied) (1000 ha)	121	25.194	13.940	2.117	37.166	7.701	1.543	19.666	2.641	10.000	0.403	0.435	VBNA 1995, Lookboek
Seed (certified) production	*2,246*	*501*	*297*	*27*	1,098	*175*	*36*	*467*	*50*	*130*	*3*	*6*	*area * yield*
Seed (certified) yield(*)	*19*	*19.89*	*21.31*	*12.54*	*29.56*	*22.67*	*23.23*	*23.74*	*19.03*	*12.99*	*8.38*	*14.35*	*(*) unless known, est. at 0.66 of aver. yield*
Total seed use (1000 t)	3,171	818	348	302	420	109	71	536	68	395	157	120	tab. 123. ZMP 1995 ZMP Bilanz Kartoffeln 95
Seed rate t/ha	2	2.39	2.04	2.56	2.33	2.53	1.22	3.05	3.40	1.48	1.44	2.31	total seed use/ total potato area
Imports of cert. seed (1000 t)	-	74	79	114	0	1	56	37	4	53	54	21	data potato trade
Exports of cert. seed (1000 t)		22	54	0	803	66	21	33	1	0	0	0	data potato trade, exports for DK & BL est. by Renia
Available cert. seed (1000 t)	2,246	552	322	141	296	109	71	471	53	183	58	27	prod. + import - export
Home saved seed (1000 t)		266	26	161	124	0	0	65	15	212	99	93	total seed use - available certified
Cert. seed used for seed (1000 t)		60	28	5	87	20	2	60	9	15	1	1	cert. area * seed rate
Cert seed use for other (1000 t)		492	294	135	209	90	69	411	44	168	57	26	available cert. seed - seed used for seed prod.
EARLIES													
Early area (1000 ha)	177	25	24	30			8	16	3	43	17	14	VBNA 1995, Lookboek
Early production (1000 t)	3,516	597	490	462			189	359	50	722	305	345	VBNA 1995, Lookboek
Early yield	20	23.88	20.42	15.40			23.63	22.44	16.67	16.79	17.94	24.64	production/ area
WARE													
Ware area (1000 ha)	1,048	222	99	86	80	12	48	140	14	213	92	38	total area - cert. seed -early - starch
Ware production (1000 t)	30,811	6,886	3,479	1,730	3,745	555	1,796	5,441	471	4,330	1,062	768	total production - cert. seed -early - starch
Ware yield	29.39	31.05	35.23	20.15	46.73	45.16	37.07	38.77	32.78	20.33	11.59	20.44	production/ area
STARCH													
Starch area (1000 ha)	190	70	34.3		62.7	23							PMB 1995, Potato statistics in Great Britain 1990-94
Starch production (1000 t)	6,256	2,217	1,201		2,106	732							PMB 1995, Potato statistics in Great Britain 1990-94
Starch yield		31.67	35.01		33.59	31.83							starch production/ starch area

6 A SUMMERY OF EU POTATO DATA 1991

	EU-12	Germany	France	Italy	NL	Danmark	Belg-Lux	UK	Ireland	Spain	Portugal	Greece	Sources
SEED (certified)													
Imports (1000 t)		74	79	114	0	1	56	37	4	53	54	21	combined national statistics
Exports (1000 t)		22	54	0	803	10		33	1				combined national statistics
Total imports (all potatoes)	721	1757	1038	916	1072	146	694	916	179	623	376	134	**ZMP 1995**
German seed				2						2	2		**ZMP 1995**
German ware			2	58	147	3	2					4	table 54 ZMP
German starch					359								VBNA 1995, Lookboek
French seed	22			4						7			Agra Europe # 789
French earlies	73				7	5	4	17		1			Agra Europe # 789
French ware	503	32		204			42	13		144	44		Agra Europe # 789
Italian early		281	23		17	16	17	5	2				Agra Europe # 788
Italian ware		31	5		2	1	1		1	0			Agra Europe # 788
Dutch seed		74	66	95	0	0	56	40	0	40	51	21	VBNA 1995, Lookboek
Dutch ware	1,041	465	39	123	0	14	217	65	22	51	46	1	VBNA 1995, Lookboek
Dutch processed (product)	674	220	99	58		11	42	149	29	41	6	19	VBNA 1995, Lookboek
Dutch processed (fresh)	1,618	528	238	140	0	27	102	358	69	98	13	46	2.4 * VBNA, 1995 figuers
Danish seed													
Danish ware													
Belgian ware					296								combined national statistics
UK seed		0	1	0	0	0	0		4	4	2	0	PMB 1995, Potato statistics in Great Britain 1990-94
UK ware		3	0	0	2	0	1		24	2	23	0	PMB 1995, Potato statistics in Great Britain 1990-94
UK processed (Fresh eq)		1	12	1	10	3	1		26	12	0	0	PMB 1995, Potato statistics in Great Britain 1990-94
Irish seed													
Irish ware													
Spanish early					2								combined national statistics
Portguses early					2								combined national statistics
Greek early													
Non-EU earlies	416	37	144	2	6	1	59	167					Savvides,1994 World Congress
Other EU earlies		393											combined national statistics
Origin confirmed (1000 t)		1,844	529	630	850	71	504	665	147	361	181	72	
% confirmed		105%	51%	69%	79%	49%	73%	73%	82%	58%	48%	54%	

6 A SUMMERY OF EU POTATO DATA 1991

	EU-12	Germany	France	Italy	NL	Danmark	Belg-Lux	UK	Ireland	Spain	Portugal	Greece	Sources
Total exports (all potatoes)	1,302	1,002	933	313	3,827	83	1,371	252	30	157	10	66	**ZMP 1995**
As seed into Germany					74			0					
As earlies into Germany	306	0	19	243						28		15	**ZMP 1995**
As raw eq. processing into germany		0	41	46	589		14	4					ZMP 1995,tab 38 +39
As starch into germany			10		41	11							ZMP, 1995, tab 66
As seed into France	78	2			67	7	0	1					Agra Europe # 789
As early into France	44			19						24			Agra Europe # 789
As ware into france	288	2			287		224	12					Agra Europe # 789
As seed into Italy		2	4		88	3	1	0					Agra Europe # 788
As ware into Italy		61	222		273		7	3					Agra Europe # 788
As starch into Netherlands		359										0	VBNA 1995, Lookboek
As ware into Netherlands		184	6	13	0		296	12		2	2	1	VBNA 1995, Lookboek
As seed into Denmark					0			0					combined national statistics
As ware into Denmark		3			28			3					combined national statistics
As seed into Belgium					56			0					combined national statistics
As ware into Belgium		2			323			2					combined national statistics
As seed into UK			1		35				1			0	PMB 1995, Potato statistics in Great Britain 1990-94
As earlies into UK			25	14			9			16	3	12	PMB 1995, Potato statistics in Great Britain 1990-94
As ware into UK		1	7		62		16		3			0	PMB 1995, Potato statistics in Great Britain 1990-94
As processed into UK		54	10	7	400	1	66		3			0	PMB 1995, Potato statistics in Great Britain 1990-94
As seed into Ireland								4					combined national statistics
As ware into Ireland					69			50					combined national statistics
As seed into Spain		2			40			4					combined national statistics
As ware into Spain					149			15					combined national statistics
As seed into Portugal		1			51			2					combined national statistics
As ware into Portugal					59			23					combined national statistics
As seed into Greece		0			21			0					combined national statistics
As ware into Greece					46			0					combined national statistics
As seed into non-EU		24			371			22					combined national statistics
As ware into non EU		143			237			52					combined national statistics
Destination confirmed (1000 t)		842	344	341	3,291	22	633	209	7	70	5	28	
% confirmed		84%	37%	109%	86%	27%	46%	83%	23%	55%	55%	57%	

6 A SUMMERY OF EU POTATO DATA 1991

	EU-12	Germany	France	Italy	NL	Danmark	Belg-Lux	UK	Ireland	Spain	Portugal	Greece	Sources
Total production (1000 t)	42,829	10,201	5,467	2,219	6,949	1,462	2,021	6,267	571	5,182	1,370	1,119	
Consumption (incl. processing)	27,516	5,940	4,112	2,417	1,311	294	1,029	5,426	535	4,210	1,505	922	ZMP 1995 ZMP Bilanz Kartoffeln 95
Seed (cert + home)	3,171	818	348	302	420	109	71	536	68	395	157	120	ZMP 1995 ZMP Bilanz Kartoffeln 95
Starch (1000 t)	6,256	2,217	1,201	0	2,106	732	0	0	0	0	0	0	ZMP 1995 ZMP Bilanz Kartoffeln 95
Market loss (1000 t)	1,563	260	744	78	145		70			242	120		ZMP 1995 ZMP Bilanz Kartoffeln 95
Animal feed (1000 t)	5,996	1,004	0	125	129	242	178	692	134	675	5		ZMP 1995 ZMP Bilanz Kartoffeln 95
% confirmed utilisation	104%	100%	117%	132%	59%	94%	67%	106%	129%	107%	130%	93%	
Market loss %	4%	3%	14%	4%	2%	0%	3%	0%	0%	5%	9%	0%	ZMP 1995 ZMP Bilanz Kartoffeln 95
Intake processing industry	6,547	2,217	1,000		2,289	732				11			ZMP 1995 ZMP Bilanz Kartoffeln 95
Intake processing industry	7,162	1,850	916	270	1,969	30	555	1,467	60	45			VBNA 1995, Lookboek
Consumption/head 1992/3	79	75	74	41	86	57	101	94	150	81	155	81	ZMP 1995 ZMP Bilanz Kartoffeln 95
1988 producers price (ware) ecu/t		96.4	73.4	176.2	70.9	123.0	44.1	96.6	96.6	147.5	127.5	200.8	EC, (1996) Agricultural statistical Yearbook 1996
1988 consumers price (ware) ecu/t			270.0	240.0	540.0	790.0	160.0	460.0	430.0	140.0	190.0	320.0	EC, (1990) consumer prices in the EEC 1988
1988 total gross margin merchants			368%	136%	762%	642%	363%	476%	445%	95%	149%	159%	consumer price/ prod. price
1991 producers price (ware) ecu/t		133.5	107.8	270.4	106.9	208.2	80.0	153.2	153.2	214.4	213.0	263.7	EC, (1996) Agricultural statistical Yearbook 1996,
1991 consumers price (ware) ecu/t		466.2	396.5	368.3	814.2	1337.2	290.2	729.5	681.9	203.5	317.4	420.2	1991 producers price * 1988 margin
1991 ware Prod. valu/ha		4,145	3,797	5,448	4,995	9,403	2,965	5,940	5,022	4,359	2,469	5,390	ware yield * prod. price
1991 producers price (early) ecu/t		238.2	222.8	500.0	194.7		279.2	196.0	196.0	288.8	242.3	224.0	Eurostat (1992) Agricultural prices
1991 consumers price (early) ecu/t		831.8	819.6	681.0	1482.9		1013.0	933.3	872.5	274.1	361.1	357.0	(Prod. price earlies * ware)/(consumer price ware)
Ware prod. cost/ha		1,571	2,130	2,693	2,098	1,647	2,121	1,580	1,460	2,471			Pepsico Foods International 1991/92
Ware prod. cost/t		39	53	72	50	41	53	41	59	92			Pepsico Foods International 1991/92
Seed purchase/ ha		308	377	424	275	285	279	322	329	318			Pepsico Foods International 1991/92
Ware prod/ha - seed		1,263	1,753	2,268	1,823	1,363	1,842	1,258	1,131	2,154			deducted from Pepsico Foods
Total potato output value	5,121	664	664	628	650	109	223	688	67	909	288	249	Eurostat 1995 statistical yearbook
Output value /ha	3,334	1,942	3,883	5,322	3,611	2,535	3,845	3,909	3,350	3,417	2,642	4,788	Total output/ total area
Output Value/t	120	65	121	283	94	75	110	110	117	175	210	223	Total output/ total production
Ware prod. price/ t		134	108	270	107	208	80	153	153	214	213	264	Eurostat 1995 statistical yearbook
Prod. valu/ha		62,234	42,985	99,591	87,037	278,409	23,220	111,763	104,474	43,630	67,609	110,817	yield * producers price
Total arable output (mio ECU)		13,230	24,745	25,732	7,166	2,286	2,449	7,871	580	16051	1986	6683	1991 data from Agricultural Statistical Yearbook 1995
Total arable area (1000 ha)		11,559	17,802	8,827	912	2,575	806	6,553	754	15258	2343	2331	1991 data from Agricultural Statistical Yearbook 1995
arable output/ha (PLA)		1,145	1,390	2,915	7,857	888	3,038	1,201	769	1,052	848	2,867	* the arable area's for Italy are extrapolated
15 % oppurtunity cost		172	209	437	1,179	133	456	180	115	158	127	430	from the years 1984-1989
		1991			1991								
Exchange rate to ECU	1.000	0.488	0.146	0.001	0.433	0.126	0.024	1.427	1.302	0.008	0.006	0.004	Eurostat 1995, Agricultural Statistical Yearbook 1995.

A 7 DISTANCES AND COST OF ROAD TRANSPORT BETWEEN EU COUNTRIES

EU transportation costs (ecu) per 1000 t by road

Based on distance between capitals (1) since that is where the majority of consumers live

ECU/1000t km = 66.6 ecu (2)

(costs -->)	Germany	France	Italy	Netherlands	Denmark	Belgium	UK	Ireland	Spain	Portugal	Greece
Germany	0	69,797	98,235	39,860	26,107	51,548	65,068	96,370	154,579	188,145	172,094
France	1,048	0	93,240	29,970	80,852	20,646	26,707	58,009	84,715	118,215	193,939
Italy	1,475	1,400	0	98,182	122,278	96,970	113,420	144,722	129,870	171,162	159,107
Netherlands *	*599*	*450*	*1,474*	0	46,633	12,348	24,276	38,661	106,334	136,483	169,990
Denmark	392	1,214	1,836	700	0	60,206	74,858	106,160	165,634	199,201	195,671
Belgium	774	310	1,456	185	904	0	16,250	47,552	105,428	138,994	185,947
UK	977	401	1,703	365	1,124	244	0	30,370	111,555	145,121	216,583
Ireland	1,447	871	2,173	581	1,594	714	456	0	142,857	176,357	238,828
Spain	2,321	1,272	1,950	1,597	2,487	1,583	1,675	2,145	0	41,292	250,416
Portugal	2,825	1,775	2,570	2,049	2,991	2,087	2,179	2,648	620	0	287,712
Greece	2,584	2,912	2,389	2,552	2,938	2,792	3,252	3,586	3,760	4,320	0

(Distance in km -->)

Source:

(1) Michelin (1996) Europe Motoring Atlas, Paul Hamlyn, London.

(2) European commission (1990), Anual report 1989, European Comission DG for Transport, Brussels

(*) Distances to and from the Netherlands have been decreased by 10 % to reflect the economies of scale.

The Netherlands carries out 25 % of all transport in the EU. Source: European Commission (1990).

Analysis and forcasts 1989 , European Commission, DG Transport, Brussels

APPENDIX A.8 LP-MODEL FOR THE EU POTATO INDUSTRY

APPENDIX A.9 MODEL OUTPUTS FOR SELECTED SCENARIOS OF TECHNOLOGY UPTAKE

If you fail to find the floppy disc
containing these appendices
at this place,
or otherwise need assistance,
please contact the Ph.D. candidate.

A.10 Publications by the Ph.D. candidate during the prescribed study period

1 Renia,H. (1995) *True Potato Seed Succesvol in de USA*. In :Aardappelwereld (49) nr.4 p.33-35.

2 Renia,H. (1995) *True seed is a commercial reality in USA*. In: Potato Review (5) nr. 3. p.49-51.

3 Renia,H. (1995) *True Potato Seed; Voraussetzung für Kartoffelsamen-Aussaat geschaffen*. In : Kartoffelbau (46) nr.8 p.334-336.

4 Renia,H. (1995) *Hoe lang houden we True Potato Seed nog buiten de deur*. In: Landbouwblad (1) no 35. p.23.

5 Renia,H.,Anderson,J.L.,DentJ.B., Lilwall, N.B.,(1996) *True Potato Seed in the European Union, an Assessment of the Economic Implications*, poster-paper, for the Annual Conference of the Agricultural Economics Society, Newcastle upon Tyne, 27-30 March 1996.

6* Renia,H.,Anderson,J.L.,DentJ.B., Lilwall, N.B.,(1996) *Modelling the Economic and Agricultural Impact of TPS-Utilisation in Countries of the European Union*, in: Abstracts of the 13th Triennial Conference of the EAPR, European , Wageningen,NL. p 34-35.

7* Renia,H.,Anderson,J.L.,DentJ.B., Lilwall, N.B.,(1996) *The Potato Industry of the European Union-15*, in: American Potato Journal 73 (8) p. 380.

8* Renia,H.,Anderson,J.L.,DentJ.B., Lilwall, N.B.,(1996) *A modelling Approach to the impact asessment of new technologies in the European Potato Industry; the case of True Potato Seed*, In: .Anderson, J.L., Renia,H.(eds.) (1996) Abstracts of Poster Papers at the VIII Triennial Congress of the EAAE Edinburgh, 3-7 September,1996, European Association of Agricultural Economists.

9* Renia,H (1996) *Science under Scarcity; principles and practice for agricultural research evaluation* (book review), in: Journal of Agricultural Economics, vol 47 No. 2 p.

10* Almekinders,C.J.M,Chilver,A.,Renia,H., (1996) *The current status of TPS technology in the world*, in: Potato Research (1996)

11 Renia,H., Anderson,J.L. (1996) *The truth is out there* in: Agribusiness 1996 (10) p. 22.

12 Renia, H , Anderson, J.L. (1996) *True Potato Seed*, SAC-information sheets, Scottish Agricultural College, Edinburgh.

* Abstract enclosed

MODELLING THE ECONOMIC AND AGRICULTURAL IMPACT OF TPS-UTILISATION IN COUNTRIES OF THE EUROPEAN UNION

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SUMMARY

A linear programming (LP) model of the potato industry of the European Union countries has been constructed to asses the impact of the use of TPS as alternative to clonal seed potatoes. Taking the 1991/92 production season as its base year, the model offers the European potato industry the option to use TPS as planting material, assuming that the agronomic and economic parameters being achieved in the USA apply. With the use of linear programming the model established the economically optimum level of TPS use throughout the EU, subject to a number of constraints.

INTRODUCTION

Recent developments in the USA, both in the fields of technology and legislation (USDA, 1995) suggest that TPS can also become a viable alternative for seed potato production in the European Union (Almekinders, et al. 1996, Renia, 1995). The regions in the south of the EU, that currently depend on imported seed, and have difficulty in maintaining a healthy seed multiplication scheme are most likely to benefit (Martinetti, 1987).

Current EU-legislation prohibits the use of TPS for commercial potato production. There is however a growing interest in the use of TPS in several European countries (Wright, 1995), which will stimulate a rethink of the current regulations. The study aims to provide the EU-potato industry and its policy makers with information about the possiblechanges that could follow from the use of American TPS varieties.

METHODOLOGY

As the actual effect of TPS in the European context can not be measured, the construction of a simulation model proves to be the best alternative (Dent et al., 1979). The potato industry is being simulated by means of an LP-model, that subdivides the EU-countries into geographic regions. Each region is allocated a large number of activities such as: production (seed potatoes, earlies, main crop ware and starch from certified clonal seed , home saved seed & TPS), storage, trade (import, export) and utilisation (fresh, processing, starch, seed, stock feed).

Each activity carries a cost/revenue, and is constrained by the access to suitable land, consumer demand, and other resource limitations.

The model is based on the 1991/92 production season, being the last without significant over or under production, and for which information is readily available throughout the community. The data collection is by way of secondary sources such as national and community statistics, publications on TPS use in the USA (Love et al., 1994) and discussions with potato experts. Additional information will be collected from field trials with 9 American TPS-varieties, that are currently taking place in the UK by the Scottish Agricultural College.

The LP model is solved whilst considering different goals such as minimum cost of total production and maximum use of certified seed. Thus the model provides information about the optimum mix of activities (under various scenarious) throughout the EU-regions. The model also provides shadow prices for alternative combinations of activities.

FIRST RESULTS & DISCUSSION

Preliminary results of the model indicate that TPS-technology can offer an economically viable alternative in many potato producing regions of the EU. Seed potato production will shift from specialised regions to places much nearer to the ware growing area's.

Critical aspects of uncertainty that affect the results of the model are: the actual performance of TPS-varieties in EU-circumstances, the effect of significant price reductions from invitro material, and customer acceptance of TPS-varieties.

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Wright,A.(1995) TPS system's rapid growth a threat to Scottish growers,Farmers Weekly 123 (17) p.57.

regation patterns of RAPD markers were studied. Ratios not significantly different from the expected 1:1 (presence:absence of a band) ratio were obtained for 29 markers. Of the remaining 21 markers, 16 (76%) showed skewed segregation in favor of the *chc* parent, whereas five (24%) segregated in favor of the *phu* parent. Of the 16 markers segregating in favor of the *chc* parent, 13 appeared to form one linkage group. Of the five segregating in favor of the 1-3 parent, four formed two separate linkage groups. Highly distorted segregation could have been due selection pressure against deleterious alleles or in favor of loci that influenced the process of haploidization through anther culture.

Renia, Hans, Stuart Richardson, Niall Arbuckle, and Andrew Skea. *SE Growers - The World's Best Seed Growing Co-Operative.*

Established in 1989 SE Growers are Scotland's largest seed growing co-operative. Members are distributed throughout Scotland, producing over 50% of Scottish seed. Scotland is at the forefront of growing seed for use throughout the world.

SE Growers offers its customers tailor made packages from quarantine facilities, through clones and mini-tubers and all stages of multiplication to the end product - the finest quality seed in the world.

In marketing and sales SE Growers are well established within the U.K. Through their established contacts and first class marketing and sales personnel SE Growers can ensure their customers the highest chance of success in the profitable U.K. market. Exports of Scottish seed can also be organized to the customers' requirements and best interests.

Co-operative production, allied to professional marketing and sales is an unbeatable combination within a highly competitive world industry. SE Growers has a proven track record and is keen to expand its business.

Renia, Hans, John Anderson, Barry Dent, and Nick Lilwall. *The EU-15 Potato Industry.*

Since 1995 the common market of the European Union (EU) consists of 15 countries with a total population of 371 million people. In 1994 the EU Potato Industry used 8% of the world's potato area to realize 16% of the world potato production. In 1995 the potato production in the EU-15 measured 44.6 million t, with an average yield of 29 t/ha and a total area of just over 1.5 million ha. The potato is currently one of the few agricultural products in the Union that has not yet been subjected to a Common Agricultural Policy-Regime. Despite the harmonization of legislation and the common economic market, major differences still exist between the member states, concerning the production and the utilization of potatoes. This paper analyzes the current regional differences and reviews possible future trends of the main sections of the EU-potato industry; namely: seed, earlies and maincrop for fresh consumption or processing, and starch. Major trade relations are also examined.

A MODELLING APPROACH TO THE IMPACT-ASSESSMENT OF NEW TECHNOLOGIES IN THE EUROPEAN POTATO INDUSTRY: THE CASE OF TRUE POTATO SEED

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Key words: New technology, potatoes, European Union

Abstract

The potato is a staple food, for which the supply of planting material is crucial. The present system of clonal seed multiplication is expensive and troublesome. True Potato Seed (TPS) technology provides a cheap alternative which eliminates many problems of the clonal system. Developments in the USA suggest that TPS can also be used in the EU. This study investigates the economic value and impact that is likely to result from the use of TPS technology in the EU. A large LP-matrix has been constructed to simulate the EU-potato industry. In the model European potato producers can meet the market demand by using clonal technology, TPS technology, or a mixture of both. The model identifies the regions that are likely to switch to TPS technology. Data has been collected from secondary sources, complemented by extensive consultation with potato experts from both the EU and USA. Results indicate that TPS-technology is attractive to many countries, especially those that currently can not meet their domestic demand.

Résumé

La pomme de terre est un produit de première nécessité, pour laquelle l'approvisionnement du matériel de plantation est décisif. La technologie de la semence vraie de la pomme de terre (TPS) présente une alternative bon marché, qui élimine beaucoup des problèmes du système clonal. Des développements aux USA suggèrent que l'on peut utiliser le TPS dans l'EU. Cette étude recherche la valeur économique et l'impact probable de l'utilisation de TPS dans l'EU. On a construit une grande matrice LP pour simuler l'industrie de la pomme de terre d' Europe. Dans le modèle les producteurs d' Europe pouvant fournir le marché avec l'utilisation de la technologie clonale, la technologie TPS ou une combinaison des deux. Le modèle identifie les régions qui adopteraient probablement la technologie TPS. On a rassemblé des données d'information secondaire, complimenté d'une consultation extensive avec les experts de pomme de terre de EU et USA. Les résultats indiquent que la technologie TPS est attrayante pour beaucoup des pays, surtout ceux qui ne peuvent pas fournir la demande nationale.

SAC receives financial support from The Scottish Office Agriculture, Environment and Fisheries Department.

ALSTON, J. M., NORTON, G. W. and PARDEY, P. G.(1995). *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Ithaca: Cornell University Press. ISBN 0-8014-2937-4. 585 pages. £27.50.

As governments throughout the world are limiting the funding of agricultural research, there is an increasing need for our discipline to quantify the effects of research and to optimise the allocation of the available resources. This book by three eminent economists from the Universities of Cornell, Virginia and Minnesota, which is published in co-operation with ISNAR, provides an exhaustive overview on the fields of research evaluation and research resource allocation. Preparations for the book started in the mid-1980's in an attempt to provide ISNAR with procedures for research evaluation and priority setting. The result is certainly impressive and according to the foreword by Vernon Ruttan it will become a benchmark in the field.

Part 1 of the book deals with the institutional and conceptual framework of research evaluation and priority setting. It begins with a description of the environment of agricultural research in terms of its various institutional settings (universities, ministries, research institutes, research councils), its wide scientific spectrum (basic, applied and adaptive research) and of course the policy context, which deals with the justification and aim of public funding. Chapter 2 gives a detailed account of the conceptual models on the effects of agricultural research and extension on agricultural production, the markets and its prices. The latter part of the chapter deals with the wide range of social objectives (economic efficiency, income distribution, income risk, self-sufficiency, etc.) that are being pursued by agricultural research. Quite often agricultural research is expected to solve social problems as a by product of its core business.

Part 2 reviews the ways to measure the effects of agricultural research. This part is certainly the most technical of the book, but the clear and consistent way of writing makes it accessible for any well motivated reader. In Chapter 3 all the relevant econometric approaches and models are presented in a clear and concise manner. Chapter 4 gives a detailed account of the economic surplus methods, which includes assessments of the horizontal and vertical market relationships and the effect of market distorting policies.

Part 3 deals with the practice of research evaluation and priority setting. Chapter 5 describes how the theory from Chapter 4 can be applied in practice to measure the economic surplus from research. The elaborate appendixes to Chapter 5 ensure that the reader is not left without a wealth of application examples. Especially the Appendix on the *Dream*© model from ISNAR provides good information for those who are contemplating a research evaluation. Chapter 6 provides a review of mathematical modelling as a tool for the allocation of research resources. Because the additional costs of modelling are small relative to those of generating the data for the economic surplus estimates, it is suggested that a mathematical modelling approach might be used more frequently in the future. Chapter 7 gives attention to various short cut approaches to priority setting. Although the use of scoring methods is not being advocated, valuable suggestions are made to bring this short cut approach more into line with the basic economic principles. This will be especially helpful for those instances when a formal assessment is not needed.

Part 4, consisting of only one chapter, concludes the book with an overview and assessment of the procedures for research evaluation and priority setting. It puts the various methods into perspective and suggests areas of future model development.

The book is not aimed at the practical assessment of individual projects but at the more theoretical assessment of whole research programmes that encompass several projects spread out over several regions, time scales and disciplines. Based on the vast experience of the authors and more than 600 references, the book provides a structured and well written overview of the field. It is pleasant to read and will be most useful as a point of reference for discussions between those who fund and those who undertake agricultural research.

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Potato Research 39 (1996) 289 – 303

Current status of the TPS technology in the world

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Additional keywords: *Solanum tuberosum* L., True Potato Seed, economic viability, developing countries, developed countries

Summary

The availability of improved True Potato Seed (TPS) varieties for short and long photoperiod conditions has recently increased the interest in the TPS technology. A summarized overview is presented of the TPS technology for potato tuber production, TPS breeding and production.
TPS competes successfully with clonal cultivars in Egypt and India. In other developing countries higher yields and better adaptation are needed to make the TPS technology economically attractive; the case of TPS in Indonesia is used to illustrate this. In industrialised countries, well-performing seed tuber programmes, productivity and legislative restrictions are difficult to beat by TPS. However, the use of TPS can be economically attractive where disease pressure is high. It is concluded that TPS has a place within potato systems where agro-ecological conditions for seed tuber systems and steady supply of good quality tubers from a formal seed programme are most constrained. Further genetic improvement will increase the areas where TPS provides better and cheaper planting material.

Introduction

The use of botanical seed or True Potato Seed (TPS) for potato seed tuber production, sometimes with the purpose of generating new cultivars, probably originated in the Andes (Umaerus, 1987; Malagamba & Monares, 1988). During the 18th, 19th and 20th centuries, farmers in Europe, Northern America and Asia also used TPS to replace degenerated material or to produce planting material when tubers were not available (Umaerus, 1987; Burton, 1989). In 1949, scientists at the Central Potato Research Institute in Shimla, India, concluded that TPS was not suitable as planting material for tuber production because the crop was too heterogeneous and low yielding (Gaur, 1990). However, in the mountainous southern part of China, where transportation of voluminous seed tubers was impossible, TPS has been used extensively in the '60s and '70s by farmers to produce their own planting materials (Song Bofu et al., 1987). Since 1977, a formal research effort to exploit the TPS potential in developing countries has been undertaken by the International Potato Center (CIP) (IPC, 1987; Umaerus, 1987). CIP's research has often been in partnership with national research programmes, which means that many developing countries and farmers have experimented with TPS (Umaerus,